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Hydrologic Engineering Center

Proceedings of a Workshop on

Policy and Procedures for Water Management, Allocation, and Conflicting Use Resolution

SP-27

30 January - 1 February 1996
Santa Barbara, California

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The Corps Hydraulics and Hydrology Branch, HQUSACE, sponsored a workshop entitled, "Policy and Procedures for Water Management, Allocation, and Conflicting Use Resolution", on 30 January - 1 February 1996, in Santa Barbara, California. The Hydrologic Engineering Center hosted the workshop and was responsible for the technical program and workshop.

The workshop consisted of five half day sessions. There were twenty invited participants who presented a total of 17 papers and three panel discussions. Participants included representatives from the Corps headquarters, division and district offices, HEC, and the Institute for Water Resources (IWR). Other participants included representatives of the Tennessee Valley Authority (TVA), Bureau of Reclamation, Lower Colorado River Authority, and two private consultants.

The primary objective of the workshop was to present papers and hold discussions on policy and procedures related to water manage conflicting use resolution that will help focus research programs in watershed studies, water use conflicts, and water management into the next century. These proceedings include a compilation of the papers and panel presentations presented at the workshop.

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FOREWORD

The Corps Hydraulics and Hydrology Branch, HQUSACE, sponsored a workshop entitled, "Policy and Procedures for Water Management, Allocation, and Conflicting Use Resolution", on 30 January - 1 February 1996, in Santa Barbara, California. The Hydrologic Engineering Center hosted the workshop and was responsible for the technical program and workshop.

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ACKNOWLEDGMENTS

Earl Eiker, HQUSACE, provided several excellent suggestions for topics and workshop participants. His efforts contributed significantly to the success of the workshop. Darryl Davis, Director, HEC, offered numerous suggestions on the format and participants and acted as moderator of the workshop. Michael Burnham, Chief, Planning Analysis Division, HEC was responsible for developing the technical content and format of the workshop, making arrangements with the presenters, and publishing the workshop proceedings. Loshan Law, Planning Analysis Division, HEC, served as administrative assistant and performed the word processing tasks associated with publishing the proceedings. Finally, the individual participants who made excellent presentations and insightful comments during discussion periods, deserve special acknowledgment in making the workshop a success.

WORKSHOP
ON
POLICY AND PROCEDURES FOR WATER MANAGEMENT, ALLOCATION, AND CONFLICTING USE RESOLUTION

EXECUTIVE SUMMARY

BACKGROUND

The U.S. Army Corps of Engineers operates 541 federally owned reservoir projects. This includes 144 locks and dams. Most of the projects were constructed between 1930 and 1980. About half were in service before 1960, and 75 percent completed prior to 1970. Authorized project purposes include: flood control, hydroelectric power, irrigation, municipal/industrial water supply, water quality, fish and wildlife, and recreation. Total storage is approximately 220 million acre feet. Slightly less than half of the storage is allocated exclusively for flood control, with 123 million acre feet designated as multiple-purpose storage.

The Corps of Engineers operates the projects in accordance with the purposes authorized by the originating legislation, or by general legislation enacted before or after the project was constructed. Water control manuals are prepared at the time of construction to document the rules and policies associated with the operation of the project. The manuals are prepared for each project. A master manual is prepared for reservoir systems involving operation of multiple projects. Water control manuals are reviewed and updated on about ten-year intervals. This ensures that operation is consistent with authorized purposes, any legislation changes, and to the extent possible, the defined needs and values expressed by communities, governmental agencies, and various interest groups. If applicable, the operation rules and policies are revised to express these changes. Revisions may be made directly by the Corps if they fall within the discretionary authority of the Chief of Engineers. Otherwise, congressional action is required to change the authorization and subsequent operation plan.

Initial operation plans are based on studies to achieve the defined authorized purposes and associated other conditions expressed in the authorizing language. Detailed studies are conducted for flood and conservation operation to derive the rules and policies. Updated studies consider changes in legislation, such as the endangered species act, increased data records, and changed project conditions. Since the late 1980's these studies have been conducted as full-fledged multi-purpose, multi-objective investigations, in an open public forum in partnership with a wide community of users, interested parties, and other federal, state, and local agencies. These update studies for individual and system water control manuals have become the forum for water use conflict identification and resolution. These types of open participation studies will continue to be a major Corps activity well into the next century. Addressing these conflict resolution studies was the focus of the Policy and Procedures for Water Management, Allocation, and Conflicting Use Resolution workshop held in Santa Barbara, California, on 30 January - 1 February 1996.

WORKSHOP SUMMARY AND CONCLUSIONS

The workshop was held to bring together a group of leading participants to share their hands-on experiences in water use conflict resolution. The objectives were to learn from each other, to and converge towards common principles and policies, and to determine which analytical tools and procedures may be useful in Corps of Engineer studies involving water use allocation conflicts. The principal goal was to produce information and general guideline materials to help focus the Corps watershed, water control, and conflict resolution research and development efforts into the twentieth century.

The workshop presentations and discussions covered a broad spectrum of topics related agency perspectives and policies, case example applications, analytical tools and methods to assist in interpreting crucial information, and proposed strategies for enabling open participation and involvement of parties interested in resolving conflicts. Agencies such as the Corps of Engineers, Bureau of Reclamation, Tennessee Valley Authority, and Lower Colorado River Authority are governed by legislation for general operation of the reservoir projects and systems. This includes project authorizing legislation and prior or subsequent legislation, such as the National Environment Protection Act and the Endangered Species Act, that affects operation. In some cases, there is direct conflict in meeting these requirements between upstream storage use and downstream releases. The point was made throughout the workshop that an initial goal of any study should be to correctly portray the existing binding operation legislative requirements. The often long and arduous procedures needed to obtain legislative approval for large-scaled deviations in existing operation plans must also be understood.

Reservoir system water use allocation in many areas is becoming more controversial and challenged as seasonal margins between having either too much or not enough water become less with increased development and water use demands. Additionally, awareness of the reservoir operation impacts by the public and interest group proponents have increase over time. The proponents are also more vocal, organized, technically and legally represented, and politically astute in defining the conflicting operation issues. The workshop case examples clearly indicated that present studies must now be conducted in a open forum with active participation from representatives of various interest groups. The workshop participants also expressed the need for better analytical methods and participatory strategies for conducting these studies in today's open involvement forum.

Several workshop presentations and discussions focussed on analytical tools and methods for water management and conflicting use studies. The need for basic understanding and overall acceptance of the analytical tools and methods by the various interest groups was deemed important. The workshop participants also stressed the importance of consensus or agreement on the existing operation plan conditions by the key study entities before alternative operation plans could be properly evaluated. The existing operation plan becomes the baseline for impact comparisons. The analytical tools and procedures were presented as aids in providing technical information that is the foundation of a study. Several presentations described applications involving simulation tools that operated for defined operation plans. Another was a prescriptive reservoir model that optimized system water allocation based on the prescribed constraints and goals defined for the system. A third performed simulation, but in an open "shared vision"

forum that enabled interest groups to model their perspective views. Another tool provided capability for an accounting type water balance analysis.

Finally, the majority of workshop participants believed they benefited significantly from sharing their experiences and opinions during the workshop. They felt others will benefit as well by reading the papers presented and assembled in these proceedings. The participants learned there are a wide range of reservoir system problems and issues, there is a broad and diverse group of stakeholders, and a variety of analytical tools and methods to assist in the study. Still, there is much more needed towards addressing the problems and finding acceptable solutions of decisions involving reservoir system operations with conflicting water use. More openness and better forums for communication are needed. The "shared vision" approach involving analytical methods with active involvement by stakeholders was thought to be on the right track. For future HEC research and development activities, the general consensus was to continue to develop analytical tools and methods that enables active participation and understanding by the various stakeholders. Also, they encouraged HEC to assist in guiding Corps users and others in our model applications and training courses towards the findings presented in this summary.

A POLITICAL AND ECONOMIC PERSPECTIVE ON WATER USE CONFLICT RESOLUTION

by

G. Edward Dickey, Ph.D.[1]
Harry E. Kitch, P.E.[2]

INTRODUCTION

We are pleased to have been invited to participate in this conference which has brought together experts from a broad range of disciplines within the Corps of Engineers and from other organizations with interests in the operation of major reservoir systems. This jointly developed presentation draws on the combination of academic training in economics and engineering and a total of 46 years of service at both policy and field levels within the Army's Civil Works Program. We hope it provides useful insights to others interested in facilitating effective management of major reservoirs which truly are important elements of our nation's water resources infrastructure.

The Challenge. The operators of large reservoir systems constructed in the past are being challenged by evolving economic activity and changing social values to produce a different mix of outputs from those envisioned when these projects were originally planned. While there have been small gradual changes in the way these systems have been operated, in recent years there has been a call for major change. Accommodation has not been easy; in some instances, value conflicts, as well as beneficiaries' self-interest, have stymied all attempts to make significant changes. There is no reason to believe that the future will be different.

In this paper we want to address three topics: Why we should want to change our systems operation; the role of the Corps in facilitating change; and why change is so difficult to accomplish.

WHY SYSTEMS OPERATING PLANS NEED TO CHANGE

Economics 101--The Production Possibilities Curve. Figure 1 is a two dimensional representation of the various combinations of two different services--say water surface area for fish habitat versus flows for hydropower-- that could be produced from a reservoir system. Note that at each point on the curve additional units of one output can be obtained only at the expense of the other--there is no free lunch. Each combination of outputs along the curve makes maximum use of the capability of the system. Obviously, this does not mean that all physical components are being fully used. For example, if water releases less than that required for full

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use of the hydropower generating capability were being made, all generating facilities would not be operating. Different mixes of outputs require different degrees of use of individual facilities and project components. If the combination of outputs being produced is not on the curve (that is, inside it), then it is possible to get more of both outputs or, alternatively, more of one at no cost to the other. Since no one would object to having more of one good without having to sacrifice any of the other, we presume we are operating on the curve.[3]

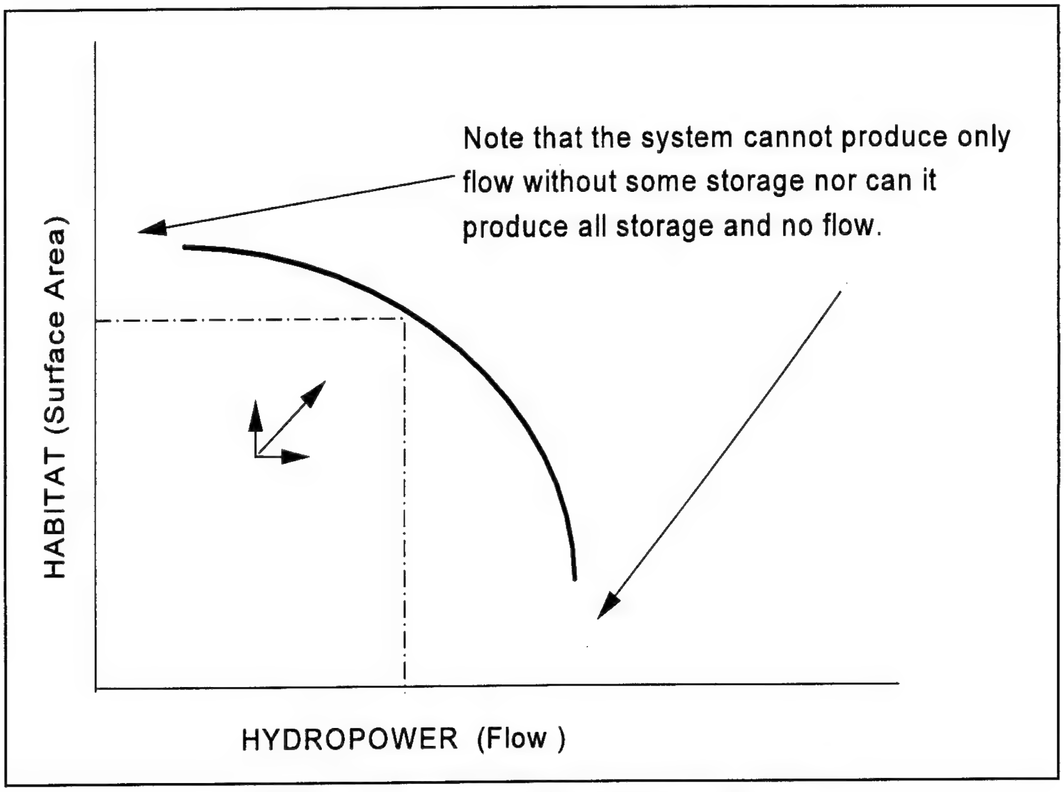

Figure 1. Production Possibilities Curve

<u>The Social Preference Function</u>. One additional conceptional construct is necessary to understand the problem of output choice and the need to adjust the mix of system outputs over time. That construct is the social preference function. This function describes how society values various combinations of outputs. One representation of this relationship is the social preference curve shown in Figure 2. A social preference curve shows the various combinations of two goods, in our case the two project services, between which society is indifferent. To fully describe society's preferences, an entire family of such curves would need to be generated. Each member of this family of curves is commonly thought of as downward sloping to the right and concave to the origin. In the simplest terms, each curve is downward sloping because if some of one good is taken away from society, additional amounts of the other good are required to keep society equally well off. Each preference function is concave because as successive equal amounts one good are taken away, society requires larger increments of the other good to keep it

[3] Implicitly, we assume that the variable inputs, such as labor, are available as necessary to operate the system to its capacity.

equally well off. All combinations of outputs can be mapped conceptually so as to produce a family of preference functions. The further from the origin a preference curve is, the higher level of social well-being. Preference functions may have different shapes as long as they are downward sloping to the right. However, no two preference functions intersect because society would not be indifferent between two "baskets" of goods if one contained more of both goods.

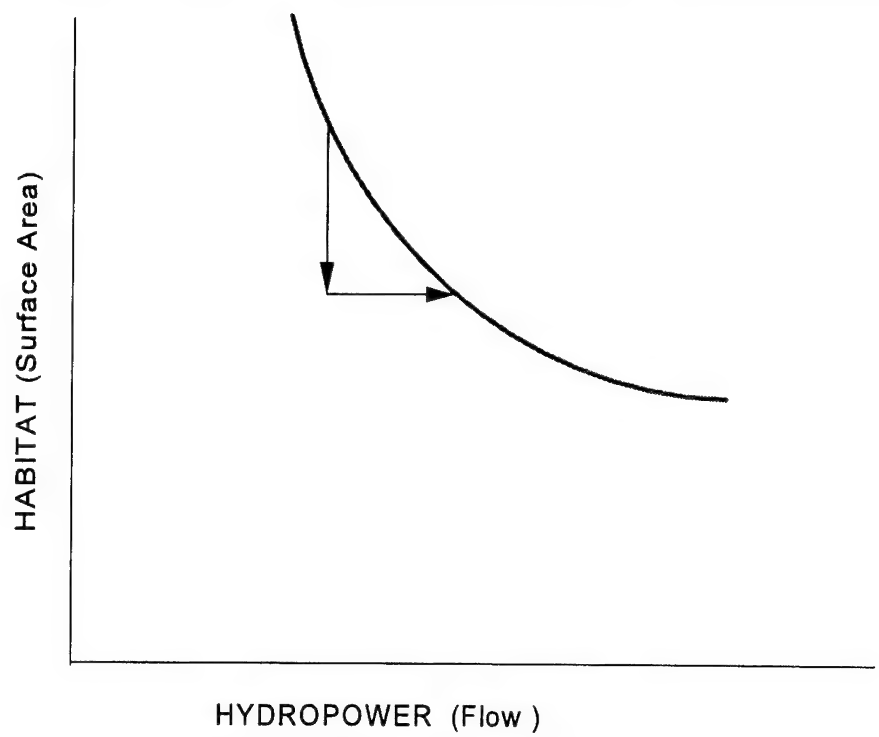

Figure 2. Social Preference Curve

<u>Optimal Mix of System Outputs</u>. Because there is considerable flexibility in our reservoir systems, there typically is a wide range of choice of output combinations. Using the tools developed above, we can see that not all combinations are valued equally. Given the capabilities of the system as reflected in the production possibilities function and the preferences of society, one combination is best. Figure 3 represents the optimal combination of project outputs given the postulated production and preference functions. The point of tangency between the production possibility curve and a social preference function represents the highest level of social benefits that can be produced. All other points on the production possibility curve would represent intersections with preference functions closer to the origin where society would be less well-off. At the time of project authorization or construction, one combination was selected as the best social choice. Because water resource project outputs are determined through political and administrative processes as opposed to through market forces, we can only presume that the best combination of outputs was selected for the conditions then prevailing.

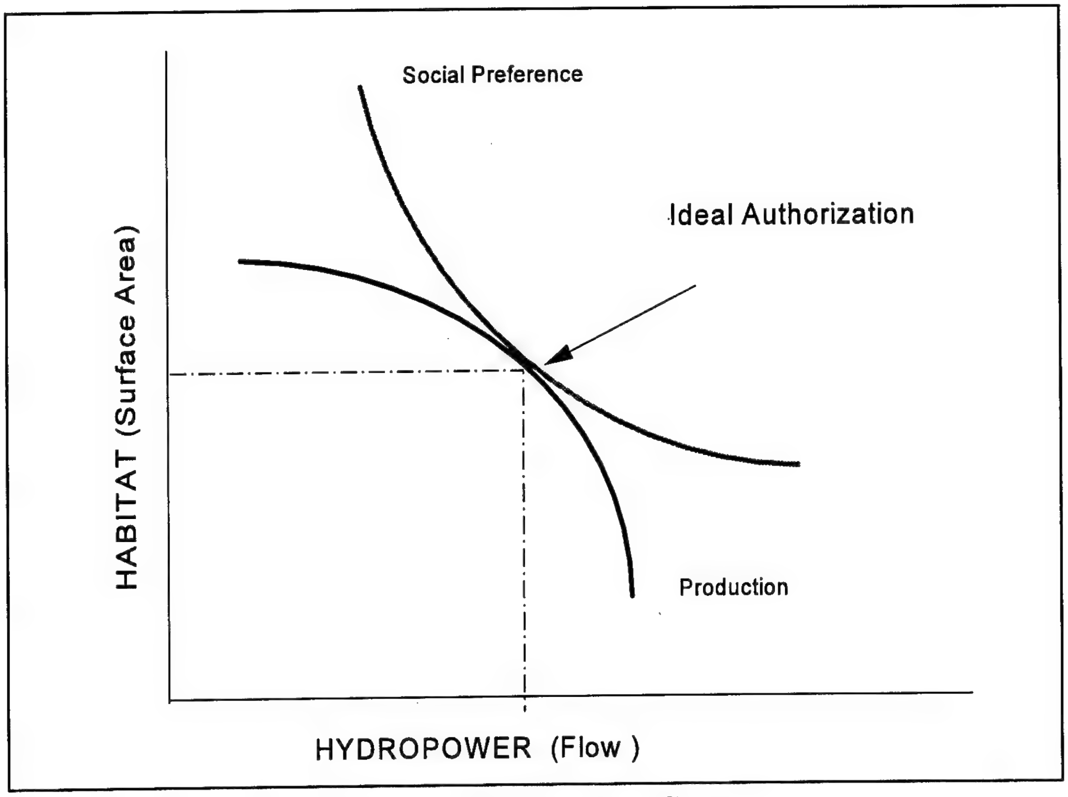

Figure 3. Optimization Curve

__The Need for Change in Output Mix Over Time__. The choice made in the past, no matter how perfect for the time, will most certainly not be the best for today or for the future for at least three reasons.

1. The national and regional economy continues to grow (Figure 4) and thereby creates different demands and thus different values (prices) for final and intermediate goods (intermediate goods are those used in the production of other goods; i.e., electricity is used to produce television programs). In turn, this change in relative values is reflected in changes in the social preference function for the services (storage and flow) provided by the dam / reservoirs since storage and flow are used to produce other goods directly valued by society.

2. Changing technology changes the productivity of the dam / reservoir itself. For example, more efficient turbines or generators can increase the amount of electricity produced per cubic foot of water (Figure 5).

3. Finally, social preferences and values change over time. Some of these changes are reflected in environmental legislation. When environmental legislation results in new constraints on reservoir operations, certain reaches of the production possibilities frontier may become no longer attainable (Figure 5). Others are reflected in how society values project outputs relative to one another and this changes the slope of the social preference function (Figure 6). Figures 4, 5, and 6 illustrate how these three factors may affect the production possibilities frontier or the social preference map. The net result of these interactions cannot be predicted.

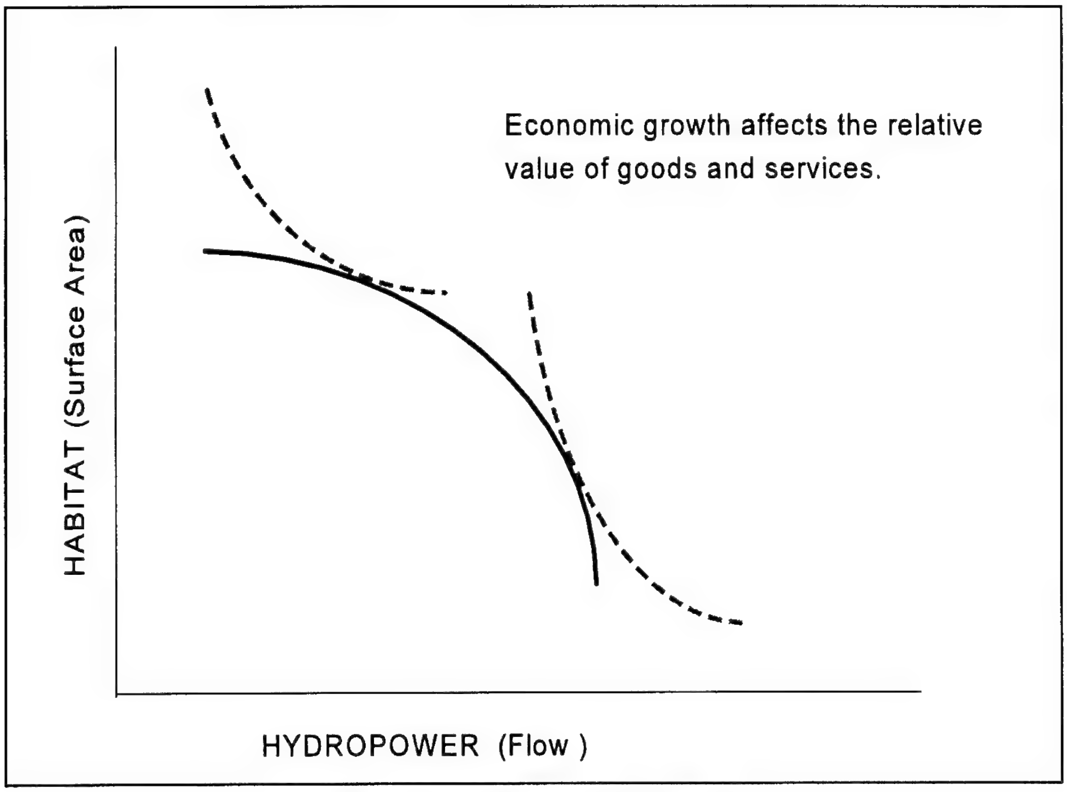

Figure 4. Economic Growth

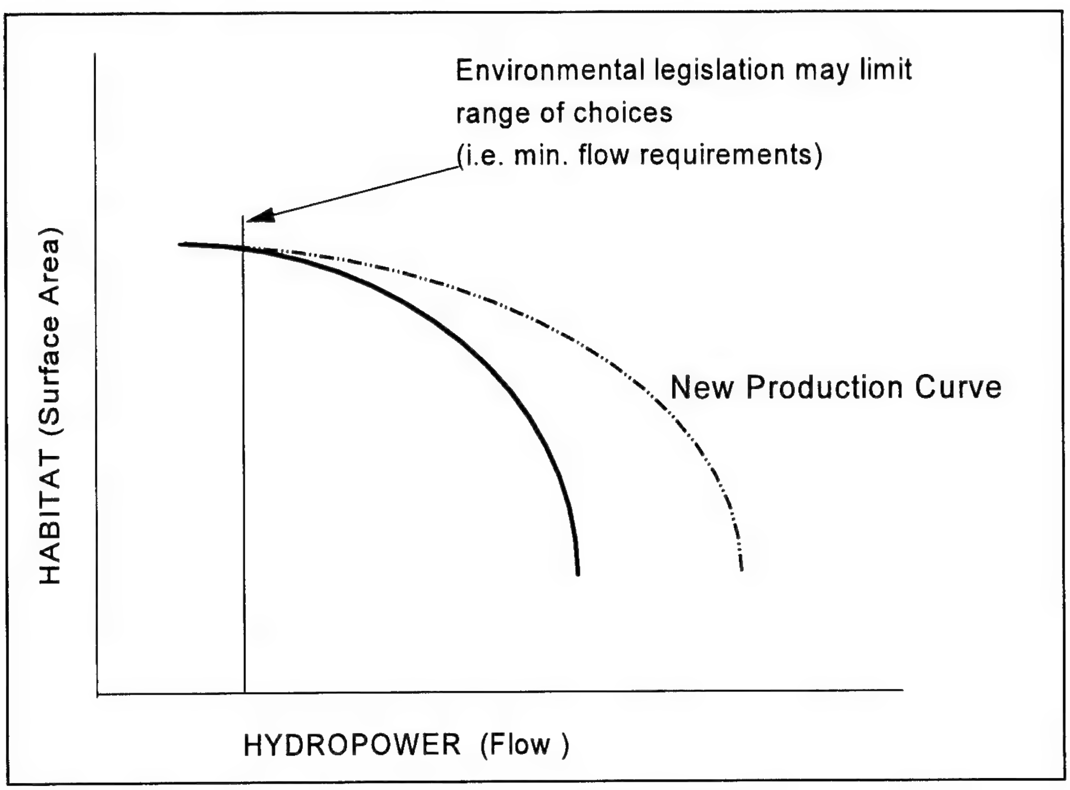

Figure 5. Technological Change

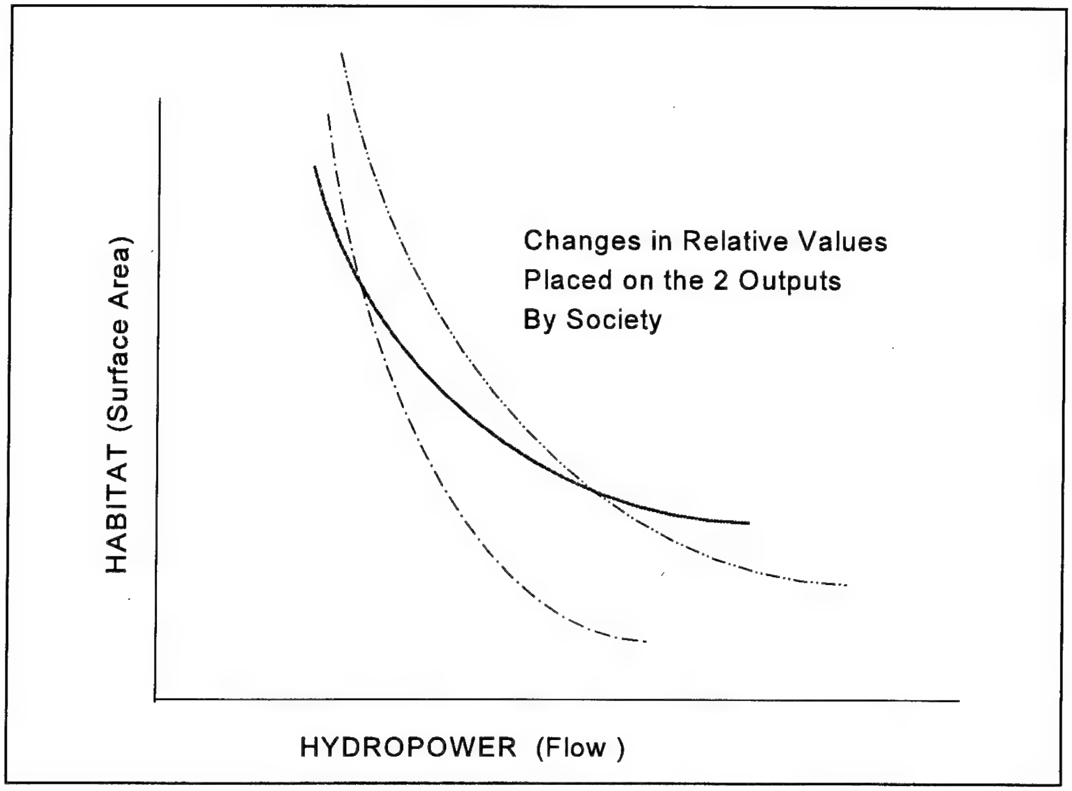

Figure 6. Social Preference Changes

It is essential that an agency responsible for the operation of large systems recognize the need for changes in systems operations and attempt to bring about change in a timely and responsible way. In the case of several of its major systems the Corps has attempted to this. Our own personal experience is with the case of the Missouri River Master Manual. In this paper we will draw upon that experience as we discuss how the Corps of Engineers can facilitate change and why change is so difficult.

THREE EASY STEPS TO A NEW OPERATING PLAN

Reanalyze the Possibilities: Define the Trade-offs. The Corps first role is that of impartial analyst. We have two major responsibilities: 1) to define the production possibilities curve as it exists today, and 2) to understand the social preference function to the extent that it can be described through economic analysis. We alone can inform society regarding the shape of the current production possibility curve. For example, changes in turbine and generator technology have substantially improved the amount of power that can be produced from a given flow of water. Accordingly, our production possibility curve has shifted to the right (Figure 5) along the hydropower or flow axis. On the other hand, we would argue that technology has not affected the relation between water surface area and habitat and, accordingly, in Figure 5, the curve has not shifted upward.

Economic analysis is also important in understanding current social preferences. Our analysis of the national economic development (NED) impacts of our different output

combinations provides valuable information about how society values different mixes of storage and flow through the values of the services produced by them. We can inform the public about the range of possible output mixes, and we can also provide them with important information about the NED value of the combinations. NED alone does not dictate choice, however, for example the spatial distribution (upstream vs downstream) of benefits is also important in making the choice.

In the case of the Missouri River Master Manual Review, we have done highly innovative analytic studies and there has been little criticism of the way we presented the choices and have valued the possible output combinations. Until recently, we have focused on the outputs of our reservoir systems to define the tradeoffs in terms of the services we provide. For example, in the Missouri master manual investigations, we tried to describe the range of choice among the economic and environmental outputs possible from the system. Surprisingly, the range of relevant choice is more limited than we first thought. In some sense, limited choice is good because it helps focus discussion. It did not however focus choice!

The only consensus that has developed so far from the review of the draft Environmental Impact Statement was that we needed to not only make more detailed studies of the direct impact of the alternative plans, but also to broaden the scope of studies through a collaborative planning process involving other agencies and programs. Apparently this means we will be looking at recreation throughout the basin and not just at the opportunities provided by our systems operation. The success of this broadened process remains to be seen.

Utilize Public Involvement to Discern Public Preferences. We do not rely on analysis alone to define public preferences. NED analysis does not fully address the environmental and social values served by our dams / reservoirs. To address these values, we rely on public involvement. As is usually the case in water resources, we are faced with several different publics. The public, however, is allied generally by occupation- farmers, shippers, water users or by advocacy- environmentalists, fishermen, duck hunters. In the Missouri River case, they also are generally grouped as the upstream and downstream interests. Just as in the production curve, we have seen changes since the original project was identified. The Corps is using its public involvement experience and techniques to attempt to discern current public preferences (Figure 6). The public involvement approach has several goals. The first is to educate all the publics on the new trade-offs that are available today. The Corps new modeling must be presented in a clear and neutral fashion so that the various groups can make informed decisions. Secondly, the public involvement program feeds back to the Corps just what the social preferences are. Unfortunately, in the real world social preferences are multi-dimensional and not as simple as we have portrayed them in our figures.

The real world has constraints. The relevant range of the production curve is limited by public preferences as expressed in law and policy. During the drought of the late 1980's in the Missouri Basin, we saw the public preferences being expressed in the trade-off's between drawing down the reservoirs for navigation and power and keeping the pools higher for recreation. The Pacific Northwest is undergoing a process of determining the trade-offs between salmon and other water resource uses. The public has forcefully demonstrated that at some point the fish must come first. There are very real constraints on the operation of the system.

The public involvement programs help to define a region of feasible solutions on the production / social preference curves. Once defined (not a trivial task), the agency can focus its efforts and the public's attention to reach an acceptable "optimum" point for system operation. The public involvement process to-date has taught us that the ideal social curve doesn't exist. We have at least two views of what would be a feasible solution (Figure 7), and they don't coincide.

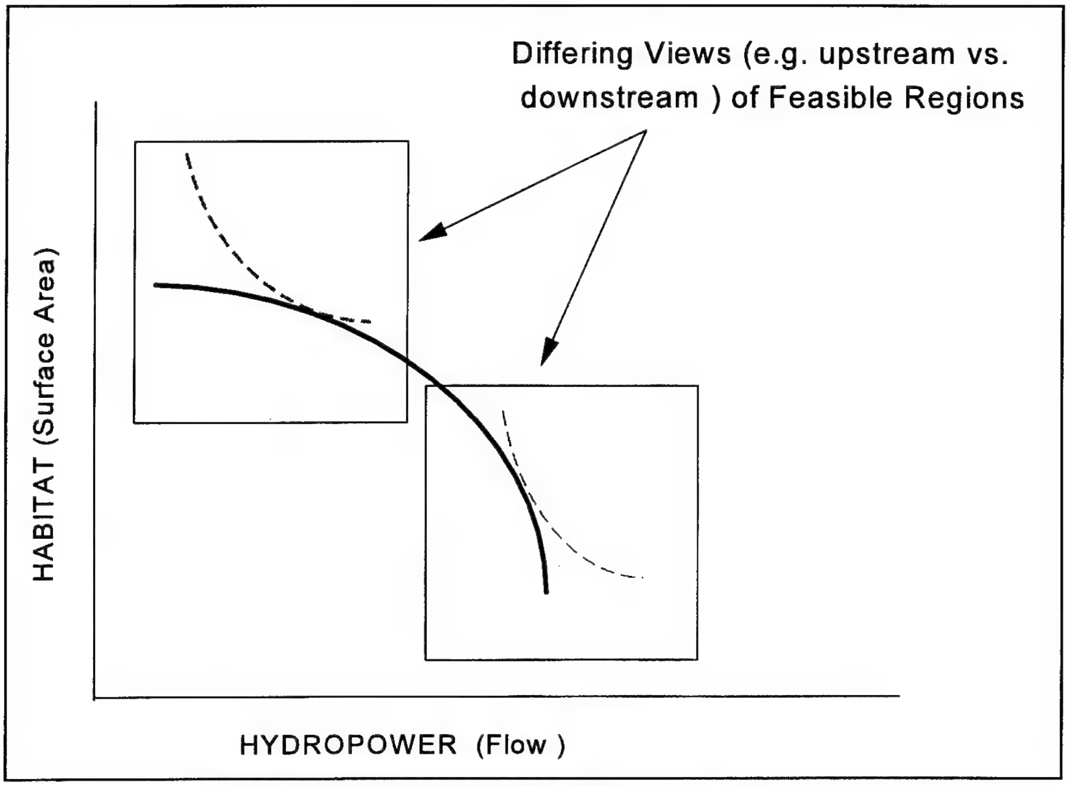

Figure 7. Real World Solutions ?

<u>Facilitate a New Public Consensus</u>. Faced with two camps with their own expressions of the social preference, the Corps' role is to try to bring the groups together. We are approaching this daunting task by promoting a dialog among the groups and proving the best information for them to use in their discussions. The commitment to a collaborative process adds many additional variables to the decision making process. We have enlarged the discussion beyond the "upstream" and "downstream" interests by reaching beyond just the reservoir areas. We all (Corps and the public) are going to have to consider solutions beyond what has been thought of in the past. Our simple production curve has been transformed into a "n-dimensional" surface well beyond what was originally envisioned when the Manual review was initiated in 1989.

WHY IS CHANGE SO DIFFICULT?

First of all the trade-offs are complex and multi-dimensional. Major changes in operating plans may result in unanticipated impacts on other outputs. For example, in the Missouri Master

Plan review there was pressure from the environmental interests to recreate in some small way the spring rise in river flows. In evaluating this scenario we carefully evaluated the direct relationships of increases in flows to flood damages. However, we missed the impacts of the spring releases on the farmers ability to get into fields protected by levees to plant their crops as a result of increasing retention of water behind the levees. This is why we must use the public involvement program to identify and make all the impacts visible.

Secondly, reality does not comport with the notion of a well-defined set of public preferences. In fact, there are a variety of publics and a great many special interests today. Part of this variety is of our own making because we have invited many more players to the table. However, the backroom deals that established the "optimum point" many years ago, are not the way that we or the public make decisions about resource allocation today. While dialogue can resolve misunderstandings, achievement of universal agreement is not a realistic goal; development of a political consensus is, and it is to that end that we should strive. Also research[4] has shown that society is not able to state preferences until the possibilities are described. The iterative process that we have described for our public involvement process does more than reveal the public preferences - it helps to shape them. Some people would therefore argue that our original postulation of independence between preferences and possibilities is naive.

Finally, the deliberative and analytical process that we prescribe, and follow in making the complicated decisions on reservoir operation and resource allocation is not allowed to be completed without premature intervention through both legislative and judicial processes. Court actions are threatened and pursued by the states and interest groups. Congress is petitioned and places constraints (e.g. P.L. 104-46 - FY 1996 Energy and Water Development Appropriations Act which prohibited springtime releases) on our actions to reach solutions. In the past, even the confirmation process for the Assistant Secretary of the Army for Civil Works was used to attempt to influence the decision making on the reservoir system. It is also clear that there is no desire to bring to closure any studies in a Presidential election year. The orderly process of identifying the trade-offs and trying to establish and identify a clear social preference has been and will continue to be disrupted by those which either wish to foreclose change or fear the consequences of change.

The Corps must recognize that social preferences have changed and that we must adapt our operations to today's realities. Such changes, however, are difficult because there is no clear picture of society's current preferences. Also the tradeoffs we must deal with are extremely complex, and it taxes our analytical abilities to clearly describe the possibilities to the public in a clear and understandable fashion. In spite of the frustration of working in this arena, it is clear that the Corps has to evolve in its thinking and in its approach to operating the Nation's water resource projects. Perhaps we need to add a Civil Works motto to the illustrious "Essayons", **"Changeons" - Let us change!**

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[4] "Shared Vision" Modeling for Environmental Project Planning, Dr. Leonard Shabman, Blacksburg, VA.

A BUREAU OF RECLAMATION PERSPECTIVE ON WATER USE CONFLICT

by

Lewis Moore[1]

The U.S. Bureau of Reclamation (Reclamation) was created in 1902 to assist in the settlement and development of 17 Western States by developing and supplying water for irrigated agriculture. Most of its extensive public works projects consisted of bringing the means of settlement to undeveloped land, but in several cases, Reclamation rehabilitated or improved preexisting irrigation projects. Administrating these projects became more complicated for Reclamation as the West spawned large urban centers while irrigated agriculture became a secondary component of the regional economy. For at least a generation, evolving demand for water from these municipal and industrial sectors has challenged the "first in time" right of irrigators who still control about seven-eights of western water.

In the last two decades, opposition to Reclamation and its client irrigators became more organized and strident. Economic and environmental challenges were brought against dam construction; maintenance of in stream flows and wildlife protection was demanded and Reclamation was increasingly viewed as the vehicle for subsidizing western irrigators to grow surplus crops[1].

Attempts to improve the efficiency of irrigation and modify allocation of some Western water have confronted stern opposition from those holding legal title to the water. Reclamation's attempts to straddle the fence between the water "haves" and "have-nots" have occasionally resulted in a policy paralysis, even when Congress directs Reclamation to make significant changes in its operations. The Reclamation Reform Act of 1982 (RRA) is one example of how difficult Reclamation finds application of externally-directed reform measures.

Reclamation continues to draw the scrutiny of clients and critics. Congress is showing renewed interest in the "irrigation subsidy" which is authorized by Reclamation Law and provided through Reclamation's operations[2]. Urban interests are maintaining pressure to modify the distribution of water for environmental and urban benefits, and Water Districts are promoting legislation that could Balkanize Reclamation and transfer many of its projects to state and local governments. In order to remain viable as an organization, Reclamation must develop an ability to broker solutions to Western water conflicts; the 1992 Central Valley Improvement Act (CVPIA) implementation is providing an important test case of whether Reclamation is up to that new mission[3].

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[1] Program Analyst, U.S. Bureau of Reclamation, WBR-5000, U.S. Department of the Interior, Washington, D.C. 20240. The opinions expressed in this paper are the author's own and do not constitute the official position of the Bureau of Reclamation or the Department of the Interior.

REFORMING RECLAMATION

Internal pressure to "reform" Reclamation has been building for the past four Administrations. President Carter's famous "hit list" was the first large caliber shot across the Reclamation's bow wave of authorized water projects. President Reagan's administration requested adequate funds for ongoing construction, but trimmed outlays for other planned projects.

In 1989, Commissioner Dennis Underwood initiated a comprehensive effort to prepare a Strategic Plan for the Bureau, addressing 26 separate areas of concern to Reclamation. This planning effort had an ambitious scope and expected to take a nearly a decade to complete -- essentially to give the Bureau a road map into its second century. Each of the sub-plans overlapped a number of others, but considerable effort was underway to reconcile the various elements of the Reclamation Strategic Plan[4] -- until Commissioner Dan Beard replaced Underwood in May 1993.

Commissioner Beard's "Blueprint for Reform" supplanted the Strategic Plan and Reclamation was overhauled in the next two years[5]. Beard brought rapid and almost traumatic change to Reclamation. The Blueprint revived the effort to downsize Reclamation by half which had been a goal of the Reagan Administration[6]. It took the large Denver Office out of line responsibilities and "empowered" 24 Area Offices with the responsibility to conduct most of the Bureau's business. This near-autonomy for the Area Offices presents a policy challenge for the Commissioner's Office which is the focus of all senior management in the greatly-flattened Reclamation organization. It also challenges consistency in promoting water transfers.

RECLAMATION'S ADVISORS (and advice)

Consultant: A decade ago, Reclamation got some very clear direction from a consultant, James Creighton:

> *If I were the Bureau, I would be greatly strengthening my ability to do operational analysis, I would be doing massive studies of what the water system in the west would look like if the institutional barriers were removed. What are the institutional barriers? How could you begin to deal with them? What are the alternative ways they could be dealt with? I would be generating some options that the politicians could begin to address. Right now, I don't think they know any options. If you guys can't generate them, then who can? Instead of fighting these changes, you should be generating the options. Instead of having George Miller come and propose legislation requiring you to do water marketing, you should be the experts of how to go about it. You should have off-the-shelf material which would let you be able to say: "OK George, you want to do water marketing? We can do it this way, this way, and this way, and it will have this effect, and cost this much and so on. Whichever way congress wants to do it is great, but here's all the ways you could do it.*

Instead, you're getting pushed, kicking and screaming, and yelling, as if it was some obscene act. You should be the experts on how to do that and you should be telling him, how it can be done[7].

Predictably and perhaps unfortunately, Reclamation didn't follow Creighton's advice. His vision was a mission very different from design and construction; it involved mediation and seriously proposing nonstructural alternatives; and, it required a good deal of political and social savvy that had not been accumulated in the previous 84 years of delivering dams. Most significantly, proposing water transfers would involve political risks to Reclamation's culture[8].

Rather than marching to Creighton's different drummer in the last decade, Reclamation largely continued in the construction cadence; the engineering tradition was firmly ingrained in most policy decisions. While there were virtually no new projects to start, the 1984 Safety of Dams Act provided the means for major retrofits of dams with structural and design deficiencies -- and work for engineers. The Strategic Plan development might have gotten to the Brave New Bureau stage -- if it had the support of two or three successive administrations, but that massive effort ended when Commissioner Beard took over in 1993. While Beard definitely brought the Reclamation marching to a halt, he did not succeed in turning the Reclamation rank and file toward a defined destination. Now under the leadership of commissioner Eluid Martinez and Assistant Secretary Patricia Beneke, Reclamation is slowly trying to take inventory and eventually begin marching again. Meanwhile, other forces and organizations have attempted to direct Reclamation's course in the resolution of water problems; several of the more important efforts are summarized below:

Interior Department: Reclamation hasn't pushed water transfers much during the last decade, but some others have. In December 1988, The Department of the Interior implemented "Principles Governing Voluntary Water Transactions That Involve or Affect Facilities Owned or Operated by the Department of the Interior[9]," principles which first stated that "Primacy in water allocation and management decisions rests principally with the States. . ." The 1988 Interior policy changed very little in the allocation of Federal water[10], but administrative and legislative events of the 1990s would attempt a glaciation of the water allocation topography in several important Western watersheds:

Congress: It was the U.S. Congress that really got into the Act -- trying to improve the "liquidity" of Western water. The most intense water allocation debate of the 1990s was, and still is, being held over the California's Central Valley Project (CVP). In 1991-92, battle lines were drawn between rival bills sponsored by Sen Seymour (R-CA) who was newly appointed by California's Governor Wilson, and the "Central Valley Improvement Act (CVPIA)," sponsored by Sen. Bradley (D-NJ) and Rep. Miller (D-CA). When the smoke cleared, on March 5, 1992, P.L. 102-575 included the CVPIA's major reform of CVP practices[11].

Today, Deputy Interior Secretary John Garamendi (with the U. S. Fish and Wildlife Service and Reclamation) is leading a massive public involvement to implement the CVPIA, but California's Central Valley farmers and their sponsors are reviving the Wilson/Seymour proposal to transfer CVP to the State[12].

Inspector General: In 1992, the Interior Department's Inspector General (OIG) completed an audit entitled "Repayment of Municipal and Industrial Water Supply Investment Costs," which recommended that Reclamation (1) establish internal reviews for insuring water delivered complies with water contracts; (2) revise guidelines to recover financing costs for irrigation water converted to municipal and industrial (M&I) use; and (3) recover proportionate financing costs for certain projects which have converted irrigation water to M&I use[13]. The following year, the OIG issued "Repayment of Irrigation Investments by Water Districts" which recommended that Reclamation tighten up on its collection processes and ensure collection of interest payments on delinquent accounts. But the report with the most immediate impact was the OIG's "Irrigation of Ineligible Lands" issued in July 1994. This report cited multimillion dollar losses accruing because interest free Reclamation water was being used either off the authorized project area or on lands which had not been classified as irrigable[14]. This issue had a lot of attention from all levels of Reclamation in 1994, but by early 1995 it had become too hot to handle because of the political opposition of some water districts; subsequently, water spreading was delegated to the Area Offices for resolution.

General Accounting Office: Water rights were also addressed in a couple of General Accounting Office reports issued in 1994. In "Water Transfers: More Efficient Water Use Possible, If Problems are Addressed", the Comptroller General's Office proposed water markets as an effective tool for more efficient water allocation and environmental improvements and it concentrated on potential adverse impacts on third parties. This report also cited Reclamation and the U. S. Army Corps of Engineers for not having adequately specified their requirements for approving water right transfers[15]; the following excerpts are from the findings of the GAO:

> *Federal reclamation and other laws can limit transfers to certain uses and project areas, and the Bureau and Corps have not adequately specified their requirements for approving transfers of water rights. [p. 3] Whether markets should be encouraged beyond the Central Valley Project is a policy matter for the Congress. A fundamental issue in developing a federal policy is the appropriate role for the federal and state governments in removing the impediments to transfers at the state level and in addressing the impacts on third parties. The Congress could [1] continue to rely heavily on the states' laws and procedures, [2] it could develop its own approval requirements and beneficial-use laws, or [3] it could encourage further changes in the states' laws. [p. 3-4]*
>
> *The Bureau of Reclamation relies on the states to address many of the impacts on third parties. But the states vary in the extent to which they review proposed transfers for impacts on local communities and the environment. Some impacts, such as those on local economies, are not addressed under some states' transfer procedures. [p. 5]*[16]

In its response to GAO's recommendation that the Secretaries of the Army and Interior "clarify guidance on approving transfers to more clearly outline the requirements", Reclamation replied with its intent to draft legislation to "address impediments to the water transfer process" while the Corps proposed to work with Reclamation and asserted that the Bureau had the primary jurisdiction over the sale of federally assisted irrigation waters[17].

The General Accounting Office's report, "Water Markets: Increasing Federal Revenues Through Water Transfers" addressed the issue of how federal revenues might be increased through market transfers of water provided through Reclamation projects[18]. That report used the Reclamation's Emery County Project in Utah as a case study and determined that a more aggressive approach could be taken in recovering federal costs. In particular, Commissioner of Reclamation should be directed "to consider charging amounts that (1) are based on Treasury borrowing rates, (2) include compound interest, (3) recover interest and power assistance subsidities, (4) recover costs throughout the useful life of the project, and (5) are higher than necessary to recover costs or constitute transfer fees, when such amounts are consistent with current law, are appropriate, and will not discourage transfers.[19]

PRIOR APPROPRIATION DOCTRINE

The prior appropriation doctrine of western water law has is one of the most formidable reasons Reclamation didn't want to enter the water rights thicket. Prior appropriation made lots of sense when the West was being settled and when economic activities, principally mining and farming, were absolutely dependent upon a sustained supply of the limited water available[20]. In the 19th and early 20th century it was essential that the original water users be granted preferential rights to water in order to invest in improvements to the land, plant orchards and construct dams, canals and other irrigation infrastructure. But this "locking up" all of existing water led to frustration of the later arrivals on the Western scene.

Because mucking around with property rights can be very threatening to those who've own those rights in toto -- for a century or more -- and, because the owners of those rights are the only constituent group the Bureau has had for its entire existence, the Bureau gave mostly lip-service to the clamor to redistribute the West's water. All the water needed by Reclamation to operate and maintain its irrigation projects, had to be acquired pursuant to state law, unless Congress provided otherwise. However, Congress chose is that the property interest, or "title," in the Reclamation project water rights (with some exceptions) is controlled by state law.[21]

Freeing up even a little water from irrigation can be difficult. Charles Wilkinson points out that if irrigators could achieve a 7 percent savings in water they apply to the land, the potential supply available to all other contemporary uses would double[22]; however, the water saved *could be lost* to the original owner, if using less water is construed (under the prior appropriation doctrine) as prima facie evidence that the original claimant had no right to the saved water[23].

THE PRACTICE OF CHANGING WATER POLICIES

Reclamation Reform Act: Reclamation's recent attempts to implement Congressionally directed changes to Reclamation Law have proven to be a legal and political minefield. The 1982 Reclamation Reform Act (RRA), for example, revised the threshold amount of land for which an owner could receive interest-free water; required the reporting of water deliveries and directed the development of water conservation plans for districts receiving Reclamation water. Interior published final rules in late 1983, but the rules were substantially revised in early 1987,

provoking a storm of protest from some members of Congress while the press raised the specter of inside deals.[24]

Amendments were added to the RRA in December 1987 and Reclamation began another rulemaking process in 1988. When Reclamation issued its Environmental Assessment (EA) for the RRA rulemaking and concluded that the impacts were primarily economic, it also issued a Finding of No Significant Impact (FONSI). In September 1988, the Natural Resources Defense Council (NRDC) sued, challenging the validity of the RRA rules[25]. The Federal District Court ruled that Reclamation had not complied with the National Environmental Protection Act (NEPA) and the Council of Environmental Quality (CEQ) regulations in preparation of the EA and FONSI. The Court directed that new interim rules and an Environmental Impact Statement (EIS) be prepared and that Reclamation promulgate final rules by September 25, 1994.

Interior appealed the Circuit Court's decision, but in September 1993, Interior, Justice and the NRDC entered a settlement contract. That contract specifies that Reclamation must propose new rules and regulations implementing the RRA in all Reclamation states and reconsider the options as part of a new EIS[26]. But political pressure remains high in this process; in early 1995, many water districts strongly objected to the draft rules which would have required "water conservation plans" as specified in the Act. As the environmental documents are now being drafted, the Preferred Alternative will recommend, but not require the water conservation plans.

Central Valley Improvement Act: The California Central Valley Project (CVP) came under congressional scrutiny in the 102nd Congress with the hotly contested bills of Senators Seymour (R-CA) and Bradley (D-NJ) vying to determine how much change would be imposed on the existing allocation of Federally-supplied water in the CVP. The "reformers" won a major victory[27] when President Bush signed P.L.102-575, but Reclamation, (which had lined up with Senator Seymour's Bill, S. 2016), found it had the formidable task of finding 800,000 acre-feet of CVP water from existing sources, modifying contractual procedures, preparing a huge amount of environmental analysis and documentation, and conducting a great public involvement process to meet the new and improved ground rules for the operation of the CVP[28].

Columbia Basin: The administrative glaciation of vested water rights also began in the Pacific Northwest where the "listing" of species of salmon in the Columbia River as "Rare and Endangered" has produced dramatic changes in the operation of Corps of Engineers and Reclamation hydropower dams[29]. Flushing flows were prescribed in a National Marine Fisheries Service (NMFS) Biological Opinion issued on March 2, 1995, which reordered Columbia and Snake River priorities making recovery of the Snake River Salmon second only to flood control and emergency power production. While Reclamation sought to purchase water from willing sellers to maintain the flows required by the biological opinion, some politicians were threatening to deny any deliveries of water for fish.[30]

Other attempts at reforming federal Western water policy are in the works[31]; and they have the common feature of pitting the water "haves" against the "have-nots" -- with the Bureau of Reclamation and Corps of Engineers straddling the political and economic fence. Sometimes state water policy comes to the rescue as in the case of "water banking" in California and the

Pacific Northwest, but as the relative supply of water declines with respect to emerging and competing uses, the balancing act becomes harder.

ONE RESPONSE TO ATTEMPTS TO REFORM WATER MANAGEMENT

One tactic which can be used when vested water rights are challenged is to remove the project from the federal inventory. Interestingly enough, the 94th Congress is considering a bevy of legislation to accomplish this. Currently, Reclamation is tracking 4 bills and 3 draft bills which could potentially transfer Reclamation projects to water districts and local government.[32] Reclamation has the policy of transferring responsibility for operation and maintenance (O&M) of projects to local entities where appropriate. While this is the case in many projects in the West, title to all those facilities remains with Reclamation. Reclamation dams which include flood control are generally operated by Reclamation in cooperation with the Corps of Engineers.

Today, Reclamation recognizes there are more opportunities for transfers to private, state or local government institutions, even the transfer of full ownership. In 1995, informal meetings were conducted with a range of stakeholders representing the varied interests in Reclamation's projects to solicit advice and hear their concerns about title transfer. Then in late August Reclamation issued a framework document outlining how title transfer will be handled[33].

Reclamation has invited project beneficiaries to offer title transfer proposals for the *uncomplicated* projects which meet the following criteria:

- The Federal treasury and, thereby the taxpayer's financial interest, must be protected.
- There must be compliance with all applicable state and federal laws.
- Interstate compacts and agreements must be protected.
- The Interior Secretary's Native American trust responsibilites must be met.
- Treaty obligations and agreements must be fulfilled.
- The public aspects of the project must be protected.
- And, beneficiaries must have an ability to meet financial obligations.[34]

Transfer of title to any Reclamation project will require legislation even in cases where project beneficiaries have fulfilled their financial obligation to the United States by paying out a project. Legislation will have to address many complex legal, policies, environmental, financial, and contractual questions. On a project-by-project basis, Reclamation will work to support title transfer legislation that addresses these issues.

Response to the invitation to title transfer is little short of amazing. Not only do the bills before the 104th Congress seek to transfer the "low-hanging fruit" which is Reclamation described above, but the hydropower and multipurpose projects as well. The California delegation has legislation ready to transfer the CVP to the water districts upon payment of the present value of the interest-free repayments contract, or about $820 million[35]. In fact, legislation, both introduced and in draft, potentially could divest Reclamation of all its water projects *and* exempt projects from NEPA. Not surprisingly, it has been the environmental community which has been most active in opposing the title transfer of Reclamation projects.

SYNOPSIS

The instant question for federal water management agencies is how to deal with the volatile repercussions from almost any attempt to administer or change the the nature of western water use. All parties must be considered, because each of those affected parties has a clutch of hot keys by which even a juggernaut water project may be hobbled. Just "implementing the law" doesn't seem to satisfy anybody, as Reclamation has seen in its effort to promulgate RRA rules.

The idea of divestiture, transferring title to the projects, is appealing to those local entities who stand to benefit from a legislative assignment or purchase of a project for the present value of the unpaid balance of the interest-free loan. However, federal divestiture is a troubling concept for many. For example, the ***Topeka Capital Journal*** recently criticized legislation drafted to transfer Corps and Bureau projects in the Republican River Valley:

> *...More than irrigation rights are at stake in this matter. Municipalities depend on some of the reservoirs involved for their water supplies. The parks and lakes are also popular for hunting, camping and fishing. That makes them an economic boost to surrounding communities.*
>
> *Then there is the matter of the investment Kansas taxpayers have made in the parks -- more that $2 million for things like boat ramps, campsites and shower facilities.*
>
> *As the bill is written, it would sell that property to the irrigation coalition for mere pennies on the dollar for what Kansas taxpayers have invested. And, that doesn't include about $50 million that American taxpayers spent on the original construction of the dams.*
>
> *All of this raises a lot of questions: How would the new owners maintain not only the improvements, but also the dams? The government spends about $500,000 a year operating and maintaining the four dams, and coalition leaders are vague on how they would absorb that cost.*
>
> *How would they deal with the cities that depend on the reservoirs for their water supplies? There are fears the new owners would raise the rates...*[36]

Just being negative about title transfer doesn't solve any problem and that isn't the purpose of this paper. Structural change is needed we must define how water can be managed in the 21st century. Reclamation is taking a different tack in its attempt to implement the CVPIA; not only are the agencies conducting public involvement, but they are involving the adversaries directly in the process of formulating the proposed policy. The same people who hurled brickbats in the past (and may again sue in the future) are participating members of a series of public forums and working teams which seem to be making progress at arriving at some consensus of how the CVP should be managed.[37]

Similar, well-intentioned government efforts have tried and failed, but this process has one more tool -- interested parties may get new of current happenings by browsing Reclamation's Mid-Pacific Region's homepage at http://www.mp.usbr.gov where minutes of the monthly meetings are archived, a tracking matrix can be displayed and a calendar of future meetings their location is kept. If browsers want more diverse views of water issues, hypertext links to a variety of California and federal water organizations are available -- just a click away.

While some will dismiss the Web's information service as gimickry, there are good reasons to believe that it is really much more. For openers, WWW is nothing like the the ponderous documents which are mailed by the truckload to "interested parties" who may need a doorstop. Search engines are quite effective in getting you to the material you want to see while bypassing what you don't[38]. Those who study the capabilities of the Internet contend that it has at least three orders of magnitude greater information transfer potential than its media competition[39].

There is also the belief that the same people who surf the Web's government and organizational domains may be many the same folks who are most influential in making policy. This has not been proven, but after gaining a working relationship with Web and developing an understanding of the exponential expansion of resources, it is difficult to tolerate the confines of traditional means of research. Finally, the Web is a two-way street. If you need more information, you can generally request it electronically. If you want to provide comment or criticism to what you see, hyperlinks generally provide that capability too.

CONCLUSION

Reclamation hasn't followed James Creighton's advice very well, because deep down, we really knew that at best, our home-grown proposals wouldn't be appreciated by most and would make others downright mad. Still, we may be evolving into the role he had in mind. Perhaps our best approach is to work directly with, rather than in quasi-isolation from, the public and the other organizations in trying to solve water problems. CVPIA will be a real test of whether there really is a "New Bureau of Reclamation" with the skills to deal with 21st century issues. One thing is very certain, water issues are not going away and their resolution is not a zero-sum game; it may be considerably more, or less.

ENDNOTES

1. See Marc Reisner, "Cadillac Desert", (hereinafter: Reisner, 1986) New York: Penguin Books, 1986. p. 500.

2. General Accounting Office, Audit Report, "Information on Allocation and Repayment of Costs of Constructing Water Projects", July 1996.

3. Department of the Interior News Release, "Garamendi Commends Withdrawal of CVP Legislation Bill 'Unnecessary'; Schedule for Administrative Action Released, May 14, 1996. "Since [Fall 1995], the Clinton Administration has held dozens of meetings at various cities in California to bring stakeholders together to develop consensus-based solutions...".

4. "Reclamation's Strategic Plan: A long term framework for Water Resources Management, Development and Protection", Bureau of Reclamatation, June 1992.

5. Daniel P. Beard, "Blueprint for Reform: The Commissioner's Plan for Reinventing Reclamation, Commissioner of Reclamation, November 1, 1993. Commissioner Beard's blueprint changed the structure and some of Reclamation policy in radical ways: It created 24 new Area Offices from for Project and local offices; the 5 Regions and the Commissioner's Office were reconfigured; and the Denver Office became staff rather than line function. Reclamation must now demonstrate it has the chutzpah to become what Beard called the "premier water resource management agency". Commissioner Beard's "reform" eliminated about 25 percent of the Reclamation employees, largely through the Voluntary Separation Incentive Program or "buyout" program. Since about a third of Reclamation's employees are within 5 years of retirement age, there is the potential for meeting the 1987 goal to reduce emplyees to 50 percent by 1998 -- without draconian means.

6. Department of the Interior/Bureau of Reclamation "Assessment '87", and its associated "Implementation Plan... A New Direction for the Bureau of Reclamation," were controlling policy documents which reordered priorities for the Bureau of Reclamation. Essentially construction was to be wrapped up and the Bureau's Operation and Maintenance budget would be augmented with the goal of improving the management of water. Structurally, Reclamation was reduced to 5 Regions and the Washington Office was downsized by about two-thirds. Substantively, Reclamation operations didn't change much. Construction still acounted for about two-thirds of Reagan.

7. James L. Creighton, "If there Were a New Bureau of Reclamation, What Role would Social and Institutional Factors Play?", Invited address to the Federal Interagency Symposium on Social Analysis and Natural Resource Agencies, Salt Lake City, August 27, 1986, p. 12.

8. See Michael Hammer & James Champy's account of organizational bias against conflict in "Reengineering the Corporation: A Manifesto for Business Revolution", New York: Harper Collins Publishers, 1993, p. 207.

9. These Interior Directives followed a proposed reorganization of Reclamation; See Cass Peterson, "Dam Builders Throwing in the Trowel", The Washington Post, October 2, 1987, p .3.

10. The Interior Water Transfer policy followed a major internal hiatus in which career Interior employees who were working on implementation of the 1982 Reclamation Reform Act were abruptly transferred to other duties. See Cass Peterson, "Interior Dept. Reverses Water Rules", The Washington Post, April 10, 1987, p. A25, (hereinafter Peterson: April 10, 1992). "These rules are riddled with loopholes big enough to drive a truck through, or a corporate farm," said Rep. George Miller (D-Calif.), chairman of the House Interior subcommittee on water and power resources. "It's a fraud being perpetuated on the Congress and the taxpayers."

11. William E. Warne, "CVP Reforms, GOP Losses Torpedo CA Gov. Wilson's Water Program" in Water Desalination Report, Vol. XXVIII, No. 46, November 19, 1992, p. 1.

12. For current events and history surrounding the CVPIA controversy, please browse http:///www.mp.usbr.gov and http://rubicon.water.ca.gov on the World Wide Web.

13. OIG/USDOI, Audit Report 93-I-468, February 1993.

14. OIG/USDOI, Audit Report 93-I-468, February 1993.

15. U. S. General Accounting Office, Report to the Chairman, Subcommittee on Water and Power, Committee on Energy and Natural Resources, U.S. Senate, "Water Transfers: More Effficient Water Use Possible, If Problems Are Addressed", hereinafter:GAO/RCED-94-35), May 1994. p. 7. "GAO's analysis of strategies for addressing the adverse impacts on third parties showed that the strategies' effectiveness varies and that no one strategy is best. Moreover, each transfer situation is unique, and strategies may effectively address certain impacts in some circumstances but not in others. Choosing appropriate strategies requires the consideration of local conditions and of existing laws and procedures. A combination of strategies is likely to be needed." [p. 3].

16. Ibid. Pages cited in quotation.

17. G. Edward Dickey, Letter to James Duffuss III, February 3, 1994. Appended in GAO/RCED-94-35. P.108-9. Reclamation has produced some draft legislation to authorize municipal and industrial water deliveries as a purpose of Reclamation Projects, but these drafts have not been introduced.

18. GAO/RCED-94-164, p. 1.

19. GAO/RCED-94-164, p. 17.

20. Charles F. Wilkinson, "Crossing the Next Meridian: Water and the Future of the West", hereinafter Wilkinson, 1992) Covelo, California: Island Press, 1992, pp. 234-5. This account tells why the "first in time, first in right" doctrine was deemed to be necessary in the seventeen Western states and how it still dominates much of the West's water policy.

21. John J. Hockenberger, Duane Mecham and Christopher B. Rich, "Filing of Reclamation Water Rights Claims in General Stream Adjucication" paper presented in U.S. Department of the Interior Office of the Solicitor Water Law Training Conference, Boulder, Colorado, September 12-14, 1995. When establishing the Reclamation program, Congress directed in Section 8 of the

1902 Reclamation Act that the Secretary acquire needed water rights under state law. Congress thus did not preempt the states' administration of non-navigable waters that the Supreme Court has found Congress granted to the public land states in the 19th Century. California v. United States, 438 U.S. 645 (1978) held that state law applies to the control, appropriation use or distribution of Reclamation project water supply for irrigation unless inconsistent with a specific federal directive. 438 U.S. at 670, 671, 679. See also Ivanhoe Irrigation District v. McCracken, 357 U.S. 275 (1958), p. 1.

22. Wilkinson, 1992, p. 287.

23. A summary of the difficulties arising from an attempt to transfer water is contained in Appendix 1, "Strategies for Addressing the Impacts of Water Transfers on Third Parties" in GAO/RCED-94-35, p. 80.

24. See Peterson: April 10, 1987, "Enraged members of Congress and environmental groups accused the bureau of giving its seal of approval to "paper farms" that will be able to use subsidized irrigation water on far more than the 960 acres to which they are legally entitled".

25. NRDC v. Underwood, No. Civ. S-88-375-LKK, NRDC on July 26, 1991, the U.S.District Court for the Eastern District of California granted a partial summary judgement to NRDC.

26. Memorandum from Commissioner Daniel P. Beard to Katie McGinty, Director, White House Office of Environmental Policy, March 3, 1995.

27. Bill Hornsby, "Water Law is Changing, Ready or Not", ***The Denver Post***, March 22, 1992. Hornsby cites the ***Congressional Quarterly***, "[the] West is bracing for a historic change in the way Congress governs the region's lifeblood -- Water. Now under attack is the traditional notion that a Western river is wasted unless it is spread over farmland or sent crashing through power-generating turbines."

28. Metropolitan Water District of Southern California, "Congress Enacts Key CVP Reforms", in ***Focus***, Nov. 5, 1992, p. 1, 6.

29. See Lisa Mighetto and Wesley J. Ebel, "Saving the Salmon: A History of the U.S. Army Corps of Engineers' Efforts to Protect Anadromous Fish on the Columbia and Snake Rivers", Seattle, WA: Historical Research Associates Inc., September 6, 1994, p. 185-188.

30. The NMFS Biological Opinion called for Reclamation to:

- ◊ guarantee provision of 427,000 acre-feet in 130.ow run-off years by 1998;
- ◊ secure an additional volume of water, in coordination with the states of Idaho and Oregon, as may be necessaty to further reduce human-caused mortality of endangered salmon; and
- ◊ secure water in a manner "consistent with applicable state law and from willing sellers."

This biological opinion calls for increasing spill of fish over dams, reductions in transportation, and the drawdown of John Day Reservoir to minimum operating pool by 1996.

31. E.g., the Western Water Policy Advisory Commission was established by the Secretary of the Interior under the authority of the Reclamation Projects Authorization and Adjustment Act of 1992, P. L. 192-575. What will the Commission do? It will review water resources problems in the nineteen Western States, examine existing and proposed Federal programs, review the need for additional water agumentation, review existing institutional arrangements, review the legal regime, and review the activities, authorities, and responsibilities of the Federal agencies with direct water resources management responsibilities.

It will examine these topics over a two-year period of research, field investigations, public discussions, and Commission deliberations.

32. The NMFS Biological Opinion called for Reclamation to:

- ◊ guarantee provision of 427,000 acre-feet in low run-off years by 1998;
- ◊ secure an additional volume of water, in coordination with the states of Idaho and Oregon, as may be necessaty to further reduce human-caused mortality of endangered salmon; and
- ◊ secure water in a manner "consistent with applicable state law and from willing sellers.

This biological opinion calls for increasing spill of fish over dams, reductions in transportation, and the drawdown of John Day Reservoir to minimum operating pool by 1996.

33. From the draft policy document, “Reclamation projects which were built for multiple purposes have potentially eligible beneficiaries including flood control, municipal and industrial water users, irrigation water users, power users, state and local governments, fish and wildlife, recreation interests, and Native Americans. As a result, title transfer of multipurpose facilities will present complicated and difficult coordination issues, potential environmental impacts and policy questions as well as complicated and intricate contractual arrangements. The title transfer "framework" suggests Reclamation will focus first on transfer of smaller, less complex projects or separable features of larger multipurpose projects.”

34. Potential transferees must be competent to manage the project and will be willing and able to fulfill all legal obligations associated with taking ownership of that project, including compliance with federal, state, and tribal laws that apply to facilities in private ownership. Full liability for all matters associated with ownership and operation would have to be assumed. Potential transferees must also be able to demonstrate the technical capability to permanently maintain project safety.

35. Adam Smith, Public Broadcasting System documentary, “Moneyed Waters”, New York: WNET, 1995.

36. “Public Should be Heard”, editorial, January 19, 1996.

37. The CVPIA Public Forum process has identified a number of issues to be addressed in the implementation of the CVPIA. Working teams were assembled for these issues, and in many cases a list of subissues associated with the main issue was created. Meetings are being held by the working teams to clarify the subissues, identify potential means of addressing the concerns, and to try to reach consensus on recommendations which will then be brought to the CVPIA Forum.

38. Lisa Corbin, "Cyberocracy", *Government Executive*, Vol. 28, No. 1, January 1996, p. 14.

39. Jay Lehr, "The Internet: Perhaps Our Finest Model of Democracy", ***E^3 Digest***, January 1996, p. 1.

PRESENT WATER CONTROL MANAGEMENT POLICIES FOR CORPS OF ENGINEERS RESERVOIRS[1]

by

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- **Project purposes are established by the U.S. Congress --**
    - specific project legislation -- e.g. public law authorizing the project
    - general authorizations -- 1944 FCA; 1958 W.S. Act; 1958 F&W Coord. Act; 1972 CWA; 1973 ESA
    - Eight purposes served -- flood control, navigation, hydroelectric power generation, municipal/industrial water supply, agricultural water supply (irrigation), water quality protection, fish/wildlife conservation, and recreation.

- **Corps operates projects to serve all *specifically authorized* purposes --**
    - Few exceptions -- need to serve a purpose identified during project formulation fails to materialize post construction; changes (either physical or social) in the basin over time obviate need to serve a purpose

- **Operation for a *generally authorized* purpose is determined on a project-by-project basis when need is identified --**
    - Examples:
      1) controlling quantity and/or quality of releases for fish can become a goal resulting from coordination with the USF&WS years after a project is first made operational;
      2) need for seasonal adjustment in lake-level guide curves for water-based recreation may develop because of urbanization in the basin decades after a project becomes operational

- **Determining whether and when to operate for a generally authorized purpose is at the discretion of the Secretary of the Army, acting through the Chief of Engineers, and has been delegated to the Division Engineers, *if it does not require permanent reallocation of storage.***

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[1] Prepared for use at the Corps of Engineers Seminar on Policy and Procedures for Water Management, Allocation, and Conflicting Use Resolution, Santa Barbara, CA, 30 January - 1 February 1996.

- **Authority in law for the Corps of Engineers to reallocate storage from specifically authorized purpose(s) to a generally authorized purpose is limited to M&I water supply --**

    - Limitation: reallocation of reservoir storage for M&IWS that would have a significant (adverse) effect on other authorized purposes or that would involve major structural or operational changes requires congressional approval.

- **Reallocating storage for purposes other than M&IWS requires Congressional approval.**

    - Minor exception -- seasonal adjustments in lake-level guide curves for a *generally authorized* purpose can be made using the Corps discretionary authority, subject to the same limitation cited in law for M&IWS (no significant effect on other authorized purposes and no major structural or operational changes required).

- **Where reservoir conservation storage has been authorized to serve multiple purposes without allocation (i.e., no amount of storage allocated to any one purpose), the level of service given to each purpose is subject tot he discretion of the Corps of Engineers.**

    - Initial water control plans usually reflect the project formulation documents used to authorized the project, however plans can and should be changed over time to reflect changing physical conditions or social changes in the basin.

    - The distribution of economic benefits among the multiple, specifically authorized purposes used to determine the benefit-to-cost ratio of the project during formulation does not govern the level of service given to those purposes.

- **The law (WRDA 90) requires that development and modification of reservoir water control plans for both specifically and generally authorized project purposes be conducted with full public involvement, to include public meetings.**

- **The implementing policy documents are --**

    - <u>Engineer Regulation (ER 1110-2-240</u> (Basic Corps WCM Policy) --
        1. Calls for preparation of water control plans
        2. Continual review and updating of WC plans
        3. Full public participation in WC plan process
        4. WC plans -- their development, modification and deviation from -- Require Division Commander's approval; *cannot be delegated*

    - <u>ER 1110-2-241</u>
        1. Lays out all requirements for Corps implementation of Section 7, 1944 FCA regarding flood control and navigation at non-Corps projects

- ER 1110-2-1400
  1. Delegates WCM responsibility to Division Commander
  2. Reinforces WC plan deviation policy
  3. Lays out responsibilities of Districts, Divisions, HQ

- ER 1110-2-8156
  1. Lays out requirements for WC Manual preparation

- Engineering Manual (EM) 1110-2-3600
  1. General guidelines and principles for WCM (how to)

MISSOURI RIVER MASTER WATER CONTROL MANUAL UPDATE STUDY

by

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THE MISSOURI RIVER MAIN STEM SYSTEM

With a total drainage of 529,000 square miles (one-sixth of the 48 contiguous states), the Missouri River drains all or parts of the States of Montana, Wyoming, North Dakota, South Dakota, Colorado, Nebraska, Minnesota, Iowa, Kansas, and Missouri. Six major Corps of Engineers reservoir projects were built on the Missouri River main stem. These are Fort Peck (Fort Peck Lake) in Montana, Garrison (Lake Sakakawea) in North Dakota, and Oahe (Lake Oahe), Big Bend (Lake Sharpe), Fort Randall (Lake Francis Case), and Gavins Point (Lewis and Clark Lake) in South Dakota. The river is 2,315 miles long and extends from Three Forks, Montana to St. Louis, Missouri. A navigation channel extends from Sioux City, Iowa, near the southeast corner of South Dakota to the mouth of the Missouri River, a distance of 732 miles.

The first of the dams, Fort Peck, was constructed as a make-work project during the Great Depression. Construction began in 1933. The remaining five projects were authorized as the Pick-Sloan Plan in the 1944 Flood Control Act. Construction began in 1946 and all but Big Bend were completed in the 1950's. Big Bend was completed in 1963. The system reached normal operating levels for the first time in 1967. The basin map presented in **Figure 1** shows the basin boundary and the location of the six reservoir projects.

The total storage capacity of the six reservoirs is currently 73.5 million acre feet (MAF), the largest storage of any system of reservoirs in this country with nearly 90 percent of the total storage contained in the upper three reservoirs. System storage is reduced by approximately 92,500 acre-feet per year due to sediment depletion. A profile of the Missouri River from above Fort Peck reservoir to Sioux City is shown in **Figure 2**. The relative size of the projects is shown in the upper right corner of the graph.

Total runoff upstream from Sioux City averages slightly less than 25 MAF per year including inflows to the 11 upstream U.S. Bureau of Reclamation reservoir projects with flood control storage. Inflows have varied dramatically from the average with total annual runoffs ranging from only 10.7 up to 40.6 MAF. The variability of runoff is demonstrated in **Figure 3**.

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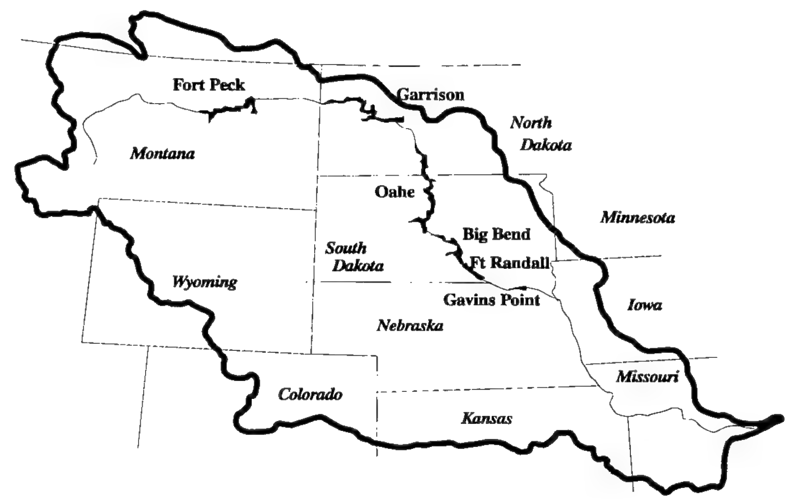

Figure 1 - Missouri River Basin

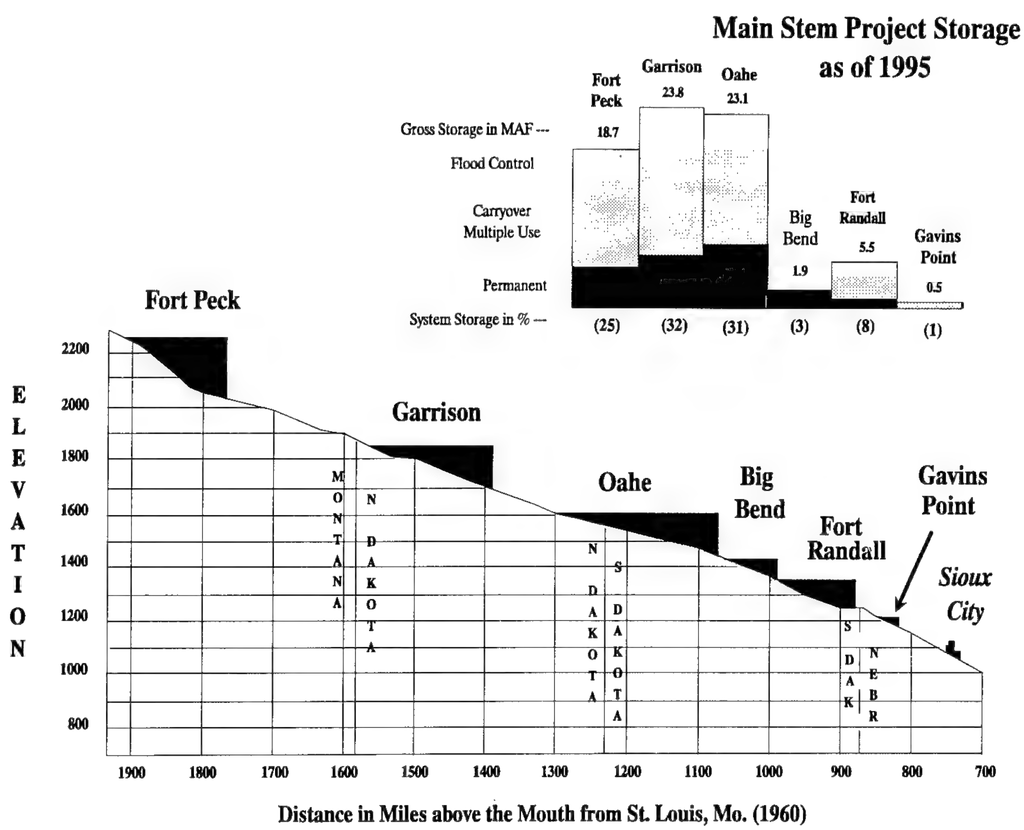

Figure 2 - Profile of Missouri River Main Stem Reservoir System

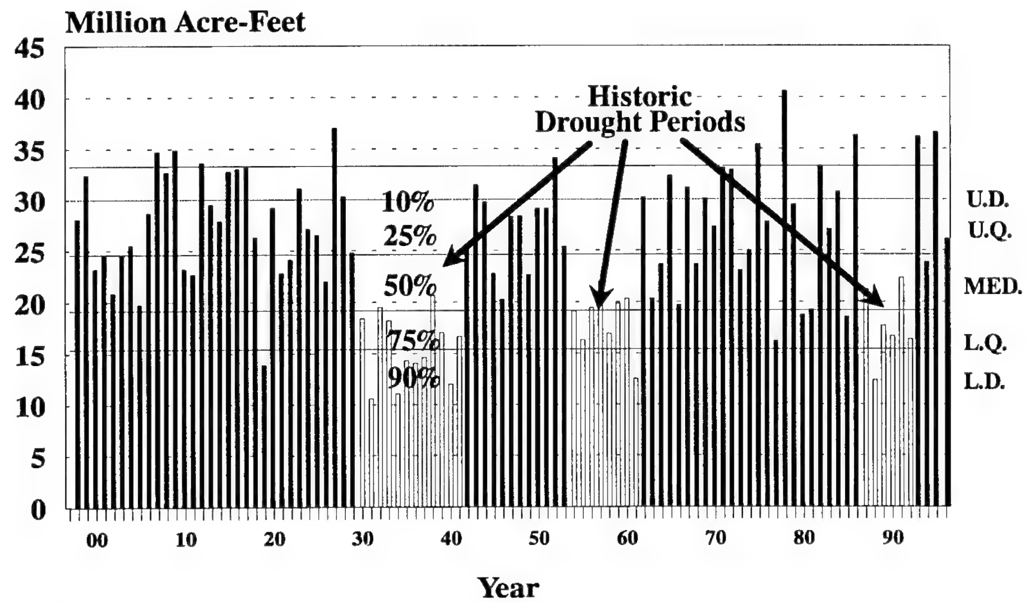

Figure 3 - Historic Runoff Above Sioux City, IA

Runoff downstream from Sioux City is extremely variable as well but, on the average, is greater than upstream runoff. Total annual runoff downstream from Sioux City, Iowa, for the 1967 through 1994 period has averaged nearly 44 MAF. Numerous Corps of Engineers reservoirs, primarily in the Kansas and Osage River basins, and 11 U.S. Bureau of Reclamation reservoirs with flood control storage assist the main stem reservoirs in minimizing flood damages.

AUTHORIZED PURPOSES

Fort Peck was originally authorized to provide flood control and navigation benefits. With the passage of the 1944 Flood Control Act in December 1944, the authorized purposes for Fort Peck were amended to be consistent with the purposes for five newly authorized reservoirs. All six dams provide hydropower. All releases, except during large release periods, are made through the powerplants. The multipurposes are:

- Flood Control
- Navigation
- Hydroelectric Power
- Water Supply and Water Quality
- Irrigation
- Recreation
- Fish and Wildlife
  - Endangered Species

DEVELOPMENT OF THE MASTER WATER CONTROL MANUALS

Studies reflecting the priority of purposes initiated with the authorization of the system. Numerous historic reports reflect the plans for system operations to support all authorized purposes. Providing needed flood control and the greatest possible support for navigation was given high priority. The Missouri Basin Inter-Agency Committee's report, "Report on Adequacy of Flows in the Missouri River," published in April 1951 reflected the attitudes that would later be incorporated in the philosophies contained in the Master Water Control Manual. The Committee consisted of basin Governors and representatives of interested Federal Agencies.

System operation began in 1953 (Fort Peck was operational, Fort Randall was closed in 1952 and Garrison in 1953) with the formation of the Reservoir Control Center. The first Annual Operating Plan for the Missouri River Main Stem Reservoirs was published in August 1953. Although the operating guides used in the development of Annual Operating Plans were in place, the first Master Water Control Manual, which documented the guidelines, was not published until 1960. Modest revisions were subsequently made to the plan reflecting a fine-tuning of regulation criteria but operational objectives remained unchanged.

Plans have always included providing needed flood control during large runoff periods. The best possible support for navigation was a high priority with a philosophy that all of the "Multiple Purpose-Carryover" storage would be used with the recurrence of the 12-year 1930's drought without jeopardizing downstream support for water supply and water quality. Use of water for downstream uses was to be limited to not preclude upstream consumptive uses for irrigation and M&I as protected by the O'Mahoney-Millikan Amendment. Paragraph 9-3, page IX-1, of the current Master Water Control Manual presents the general approach which was generally agreed upon during the planning and design of the reservoirs.

<u>First</u>, flood control will be provided for by observation of the requirement that an upper block of storage space be vacant at the beginning of each year's flood season;

<u>Second</u>, all irrigation and other upstream water uses for beneficial consumptive purposes during each year will be allowed for;

<u>Third</u>, downstream M&I water supply and water quality requirements be provided for;

<u>Fourth</u>, the remaining water supply available will be regulated in such a manner that the outflow from the system provides for equitable service to navigation and power;

<u>Fifth</u>, by adjustment of releases from the reservoirs above Gavins Point, the efficient generation of power to meet the area's needs consistent with other uses and power market conditions;

<u>Sixth</u>, insofar as possible without serious interference with the foregoing functions, the reservoirs will be operated for maximum benefit to recreation, fish and wildlife.

NEED TO UPDATE THE WATER CONTROL MANUAL

The Missouri River main stem reservoirs were all first filled to normal operating levels in 1967. Over the next 20 years, the system operated primarily in the flood control zones as the year-to-year runoff into the system was near normal. In the meantime development of the uses relying on the reservoir levels and river flows grew, and the dependence on the main stem system for economic growth and viability increased.

Beginning in 1987, inflows into the main stem system began to drop below normal levels. In the previous 20 years, a low inflow year or two was followed by a very wet year, which refilled the system to "normal" levels. This did not happen in 1988 when the lowest inflow year since 1940 occurred. A major decline in the amount of water in system storage occurred that year with the accompanying dramatic increase in economic losses to some of the users. Those users most dramatically affected were primarily dependent upon the reservoir levels, which dropped substantially in 1988. Many of the recreation facilities were located in the upper reaches of the reservoirs or were constructed in bays protected from wind to avoid the very large waves that sometimes develop on large bodies of water. In contrast to the upstream users, downstream users were relatively unaffected in 1988. Commercial navigation, one of these users, had just gone through a decline from a maximum annual tonnage of 3.3 million tons (excludes sand and gravel and waterway materials) to lower levels averaging about 2.5 million tons over the 1978 to 1987 time frame. As the drought persisted into 1989, adverse economic impacts in the upper basin states also persisted and notable impacts began in the lower basin states.

The upstream states perceived that downstream states were largely unaffected by the drought while they were being severely damaged by falling water levels causing recreational facilities to become unusable. Elected officials from upstream states, both Governors and Congressmen, brought great pressure on the Corps of Engineers to reduce releases and retain more water in the reservoir system. A commitment was made in October 1989 by the Division Commander to do a thorough review of the Master Water Control Manual to determine if a revision to the plan was needed to meet the contemporary needs of the basin. Changed conditions include not only adjustments in priorities but added release requirements for the protection of endangered species and greater winter releases to satisfy downstream water intakes.

STUDY METHODOLOGY OVERVIEW

As the Master Manual study methodology was being developed, existing data and models were evaluated to determine the most expedient way to delineate impacts for alternative water control plans for the initial 6-month-long comparative economic analysis of alternative water control plans. It was readily apparent that data was extremely scarce; however, the existing Long Range Study Model (LRS Model) provided an excellent basis for delineating changes in reservoir storage levels and river flows for historic inflows to the Missouri River main stem reservoirs and the navigation project in the lower river (main stem system). From the LRS Model output data, economists were able to relate potential economic losses resulting from reduced reservoir levels in the drought periods and the extremes in river flows in both drought and flood periods.

An initial analysis of 22 alternatives indicated that additional studies were warranted. Public input to the study also indicated that the Corps was going to have to continue to evaluate a wide range of alternatives. Delineation of impacts over a wide range of conditions emphasized the need to analyze the historic period (1898 to current) modeled in the initial studies. Also, an environmental impact statement (EIS) was going to be required, which emphasized the need to delineate environmental impacts for the alternatives. Based on these factors, an efficient way of evaluating impacts had to be developed that could delineate impacts over a 96-year period of record for a large number of economic uses and environmental resource categories. A computerized analysis was the only way to provide the required efficiency, and the Corps explored alternative impact analysis techniques.

A three-step study methodology developed. Hydrologic modeling would be based on the continued use and improvement of the monthly time step LRS Model. Value functions would be computerized that related economic use or environmental resource impacts to outputs from the LRS Model, including reservoir level and river flow changes. Finally, computerized outputs would be developed to display impacts for review by the study team and decision makers, to determine additional alternative formulation needs, to select a preferred alternative for public review, and to provide impact data for incorporation into an EIS.

The study methodology was developed in an iterative process that involved expertise from the affected states and with other Federal agencies. The basin Governors established a coordinating committee up-front that worked with the Corps until the Missouri Basin States Association was reformed and took an active role in the study. The Indian Tribes obtained membership in the Association, and it was subsequently called the Missouri River Basin Association (MRBA). Various Federal agencies participate in MRBA meetings; therefore, they had the opportunity to monitor Corps progress and provide input. Some agencies such as the U.S. Fish and Wildlife Service, took an active role in the study from its onset. The states involved special interest groups in coordination efforts to provide and receive information to provide input regarding the study methodology. Throughout these coordination efforts, it was readily apparent that considerable expertise was there to draw on and there was a need for considerable information expressed by all involved.

HYDROLOGIC MODELING

Modeling Options. The LRS Model is a descriptive model specific to the main stem system. Historically, this model has been used to study different regulation scenarios to determine the feasibility of each, considering the goals and constraints of the system. In 1990, the development of another model was initiated as a result of the Master Manual study. This was the HEC-PRM, a prescriptive reservoir model developed by the Hydrologic Engineering Center. The HEC-PRM also modeled the main stem system but strove for an optimal allocation of system water based on defined goals and constraints of the system.

In using the LRS Model for Master Manual study, the goal was to model a multitude of regulation alternatives and then analyze the results based on value functions (based on benefits) that related the economic uses and environmental resources to changes in the main stem system. By utilizing the HEC-PRM, however, the result would be a regulation scenario based on penalty

functions (based on costs, or lost benefits) of the economic uses and constraints of the environmental resources. Preliminary results of the HEC-PRM indicated problems with the relatively high value of hydropower compared to other system purposes, the difficulties in properly portraying environmental resources as constraints, and the lack of a procedure to develop operation plans from the results. By the time the HEC-PRM model was more fully developed, the use of the LRS Model was well established. Due to time constraints in Master Manual study schedule, a decision was made to continue using the existing LRS Model and perhaps use the HEC-PRM at a later date.

The LRS Model. The LRS Model was created in the 1960's to evaluate regulation criteria for the Missouri River main stem system for all authorized purposes under widely varying hydrologic conditions. The model was updated and modified for the Master Manual study. It is a simulation model specific to the main stem system and reflects the need to balance the high runoff due to snowmelt and spring/summer rains, hydropower requirements, flow requirements for fish and endangered species, and support navigation flow requirements during the ice-free months of April through November.

The model uses monthly flow data and contains 12 nodes, including the six dams and six stream gaging locations of Sioux City; Omaha and Nebraska City, Nebraska; and Kansas City, Boonville, and Hermann, Missouri. Lake Sharpe and Lewis and Clark Lake have a relatively small storage volume in relation to the volume of water that passes through them in a month's time, so variations in storage are not considered in the model. A 96-year period was modeled, from March 1898 through February 1994.

Input data includes historic reach inflow from 1898 to the present for each node and factors (depletions) that adjust the historic monthly inflow to current water uses. Also included are the various constants and variable parameters that define regulation decisions. Program considerations include (1) reductions in historic inflows to reflect current levels of water uses, (2) reductions in reservoir volumes to reflect continued sediment accumulations, (3) reductions in tailwater levels due to degradation, (4) reservoir evaporation, (5) factors for determining the amount of tributary inflow that is available for meeting navigation targets, and (6) seasonal flow limits for flood control, navigation, hydropower, water supply, irrigation, endangered species, and evacuation.

Various modifications were made to the LRS Model to account for environmental considerations. Certain minimum flows were maintained during the fish spawning season if flood control criteria permitted, and certain releases were maintained below maximum levels for the endangered or threatened birds. Also, attempts were made to provide a high rising spring reservoir level in at least one out of 3 years in each of the upper three reservoirs to enhance reservoir fish reproduction. This was also keyed to having alternate high and low river flows between these dams for native fish and endangered or threatened birds.

The LRS Model produces monthly output for various parameters for each node and for the system in yearly blocks. A number of supplemental programs were written to assist in analyzing the results of the various alternatives. Data computed by the LRS Model is written out to a set of files that are then used to evaluate economic and environmental impacts, while another

produces either graphical or tabular results of parameters requested by the user. Revisions were also made to the LRS Model to produce output data at additional locations keyed to various economic uses.

The Daily Flow Model. The LRS Model is a monthly time step model utilizing average monthly flows or releases and end-of-month reservoir elevations. Using a monthly model does not provide data to completely depict impacts to certain aspects of the system. Work was begun on a daily model while earlier efforts on the Master Manual study were in progress, but due to workload and time constraints, it was not completed when a Draft EIS was distributed to the public in July 1994. In response to comments received on the Draft EIS, renewed interest in a daily model led to the further development of the Daily Flow Model (DF Model). It is currently anticipated that this model will be fully operational in late 1996. This model is also a simulation model specific to the main stem system. It uses available daily flow data for the period 1930 to the present and contains 16 nodes including the six dams and ten stream gaging locations of Sioux City, Iowa; Omaha, Nebraska City, and Rulo, Nebraska; St. Joseph, Kansas City, Waverly, Boonville, Hermann, and St. Louis, Missouri. When completed, the DF Model will also have the flexibility to model various regulation alternatives, with the option to review results in either a daily or monthly format. The DF Model will be, in effect, a much finer-tuned LRS Model as it will include all the aspects of the LRS Model with all the benefits of 1990's technology.

IMPACT IDENTIFICATION USING VALUE FUNCTIONS

As discussed earlier, several factors led to the use of value functions to represent relationships between reservoir levels or river flows and the "value" of a specific economic use or an environmental resource. This concept initially provided some flexibility in terms of the hydrologic modeling. The way the economic value functions were established allowed the conversion of the values to "penalties" for the penalty functions required for the prescriptive reservoir model hydrologic model. No matter which hydrologic model was ultimately selected, there would always be a need to quantify the impacts of the alternatives, which required value functions, particularly for the environmental resources, which were treated as constraints under the prescriptive reservoir modeling approach.

Economic Use Impacts. Economic value functions were developed for five use categories -- flood control, navigation, hydropower, water supply, and recreation. The specific approach followed for each economic value function was unique, yet each one was developed such that project benefits, or value, in terms of dollars could ultimately be computed for each use. Required computational processes for each economic use were coded into computer language and combined into an overall "model" referred to as the Economic Impacts Model, which has five modules, one for each of the five use categories.

The flood control module calculates benefit reductions, or damages, incurred from high water conditions that would affect structures and crops located in the flood plain. This module has the capability to process up to 17 river reaches, one for each LRS Model river reach. Navigation losses due to shutdowns during very high river flows are estimated in the reaches in the lower Missouri River. For a given reach, the flood control module processes average monthly river flow data from the LRS Model by combining them with a file of incremental

differences between the historic average monthly flow and the historic peak monthly flow for each month in the period of record. If a combined flow for a given month is great enough to cause flooding, the module will find the peak of the flood (if the duration is in consecutive months) to determine damages for that event. The module will not attempt to compute damages for a given event until the monthly peak recedes below the zero damage point on the flood control value function for that reach. Maximum flood damages for each reach are determined for a run-of-river alternative (assume no flood control for the main stem dams), and these values are assumed to be the maximum attainable benefits. The compiled (summation of all 17 reaches) computed damages for any other alternative are subtracted from these compiled maximum attainable benefits to arrive at the flood control benefits for the alternative.

Economics of navigation on the Missouri River are affected by the level of service provided (full, minimum, intermediate levels, and no service) and the season length. The navigation module calculates the benefits for a given month based on the service provided for each month of the normal 8-month season (and an additional 10 days when excess water in storage allows for an extended season). It computes these benefits for a given set of commodity types recently transported on the Missouri River, including farm products, food products, chemicals, building products, petroleum products, sand and gravel, waterway improvement materials, and "other" products. Variations in navigation channel operation and maintenance costs are also handled by this module. The lower Missouri River is divided into four reaches (Sioux City to Omaha, Omaha to Nebraska City, Nebraska City to Kansas City, and Kansas City to the mouth). The total Missouri River benefits for a given year are comprised of the summation of benefits for each month for all 4 reaches.

Mississippi River navigation benefits were analyzed by the Corps' Mississippi Valley Division. This analysis was done independent of the Economic Impacts Model. The average monthly flows computed by the LRS Model were added to daily average flow data already available for the Upper Mississippi (and downstream tributaries for Lower Mississippi River impacts) to arrive at flows at St. Louis, Missouri and Cairo, Illinois. The resulting daily flow values were used as input to a navigation model that computed increased navigation costs as flows diminished below specified levels. The resulting costs were subtracted from an average annual navigation benefit under unconstrained navigation conditions of $1.7 billion to arrive at the annual benefits for Mississippi River navigation.

Hydropower benefit computations rely on hydropower generation data provided by the LRS Model, which provides estimates of the monthly energy in kilowatt-hours (kWh) and monthly capacity in kilowatts (kW) for each of the six reservoir projects. Value functions describe the replacement value of energy and capacity to apply to the LRS Model output for each month. Replacement values are used because there are currently plans to add power generation facilities in the region within the next 5 to 10 years, which will need to be expanded if hydropower generation is diminished by main stem system operation. Total hydropower benefits for each month are derived by summing the energy and capacity benefits for all six projects.

The water supply module calculates costs incurred from low water conditions that would affect water intakes or the discharge of thermal wastes from powerplants (other water quality needs were adequately served at the minimum flows modeled in the alternatives). Intakes

include those serving domestic, powerplant, irrigation, municipal, public, commercial and industrial, and rural water supply. Water supply value functions basically describe the monthly expenditures associated with operation and maintenance, renovation costs, energy costs (powerplants only) and/or new investment costs at each intake category. The thermal waste cost is the lower computed value for two options: 1) buying replacement power for the period of low flow or 2) replacing plant capacity early or building a cooling tower (30-year life assumed for either improvement), whichever is most applicable for a given powerplant. Benefits for optimal conditions at each intake/powerplant are defined for each reach, and the expenditures computed from the value functions for each reach are subtracted from these benefits. Total benefits are the summation of the residual benefits for each reach.

Recreation benefits accrue from main stem system operations on both the reservoir and river reaches. The recreation module has the capability to process all 23 reaches included in the Economic Impacts Model. For a given reach, the recreation module processes each month in the period of analysis by determining if capital costs for improvements or visitation loss should be included from a predetermined optimal condition. The capital cost value functions describe the expenditure needed for the continued service of recreation facilities. When the useful life of a facility is exceeded, renovation costs are considered if the water levels are at the level that caused the original expenditure, e.g., boat ramp extensions. Visitation loss functions estimate project visitation losses due to reduced river flows or lower reservoir levels. For the reservoir reaches, the visitation is affected by what happened the last 3 years, i.e., whether the reservoir is higher or lower over the period. For the river reaches, the visitation loss is based on each month's flow, or elevation. Total recreation benefits in each month are computed by summing the benefits for all 23 reaches.

ENVIRONMENTAL RESOURCE IMPACTS

Environmental value functions were developed for wetland/riparian habitat (i.e. habitat for various wildlife using the river and its adjacent lands), various fisheries (native or warm river species, cold river species, warm reservoir species, and cold reservoir species), endangered and threatened bird species, and historic properties along the three largest reservoirs. The value functions are, again, unique for each resource. They are so unique that they have differing units or indices instead of units of measure. The selected "values" are based on some factor that depicts potential benefits for the environmental resource being analyzed. For example, increased acres of clear island habitat in certain river reaches is expected to be beneficial for the two bird species of concern -- the endangered interior least tern and the threatened piping plover. Nine resource value functions were developed for the Master Manual study that were coded into computer language, and the resulting seven resource modules (two of the modules computed values for two resources) were combined into an overall "model" referred to as the Environmental Impacts Model.

All five environmental modules shared some common procedures and characteristics. If the module was developed to calculate a monthly resource value, a 12-month by 96-year matrix of values for each site/reach was the output in a specific format. The monthly values could then be combined and output into a yearly format (1X96 matrix) by site/reach that was identical to the format for resources that were developed to calculate only a yearly value. The 1X96 values could

be combined into a single value (average annual) for each site\reach, and these values combined into a single resource value for the entire system. As with the economic values, any level of detail could be used to compare the value of a resource for any alternative.

The reservoir fish production module was one of five fish modules. Through consultation with biologists familiar with the six main stem reservoirs, a methodology was developed using the first year abundance data of various cool- and warmwater species in the reservoirs. These data were related with various hydrologic variables to determine which of these variables may significantly affect the abundance of these young-of-year populations. Multiple regression was the technique used to determine the combination of these variables that best predicted the abundance of each species in a reservoir. Through consultation with the biologists involved in the analysis, certain of the species were selected based on the ability to develop the predictive equations and the relative importance of the species in each reservoir. Each of the species was weighted equally, and their predictions combined into a yearly index. The indices were weighted based on the relative size of the reservoirs to arrive at a value for each of the six reservoirs that could subsequently be combined into a single value for all of the reservoirs.

Reservoir coldwater communities exist at the four largest reservoirs. These species provide specialized angling opportunities not normally available in the Missouri River basin. The relative effect of system operations on the amount of water in the reservoirs meeting coldwater criteria (defined as being equal to or less than 15 degrees C and greater than or equal to 5 parts per million of dissolved oxygen) was determined to be a good indication of the viability of this segment of the fish population in these reservoirs. An existing water quality model, CE-QUAL-W2, was adapted and run with a wide variety of operating alternatives so that a wide array of potential hydrologic conditions were included. The output was used to develop month and reservoir specific regression equations that related monthly reservoir levels, inflows, and outflows to the volume of coldwater habitat. The module computed the monthly coldwater volumes in each reservoir from which the minimum volume in MAF was identified to depict the annual coldwater habitat value for each year of the period of record.

Both river cold- and warmwater fisheries are addressed in one module. This module evaluates the amount of optimal habitat available for the river coldwater fish community below Fort Peck Lake and Lake Sakakawea and the warmwater fish community below Fort Peck Lake, Lake Sakakawea, and Lake Francis Case. The coldwater community includes important sport fish such as rainbow trout and chinook salmon and the warmwater community includes the endangered pallid sturgeon and other native species. System operations could affect the length of river downstream from these reservoirs that meet specific temperature thresh holds in predetermined months for these communities that could affect growth, survival, and, ultimately, the abundance of these species. The riverine water quality model CE-QUAL-RIV1 was used to simulate river temperatures under various combinations of a wide range of average monthly reservoir releases, release temperature (from reservoir coldwater module), equilibrium temperature, and hydropower peaking index in each reach. Output from this effort was fit to a logistics equation to generate values of the equation's coefficients. These data were used to develop regression equations relating the coefficients to LRS Model outputs. Module computations generated, when linked to LRS Model outputs for the alternatives, the number of miles that met the temperature thresh holds for each month. These were averaged for the months

computed to obtain an annual value for each year of the period of record for both the warm- and coldwater community.

The native river fish physical habitat module evaluates the impacts of alternative operations on the water depth and velocity components of the habitat for native river fish. Because these species include one Federally listed endangered species, the pallid sturgeon, and other candidates for listing under the Endangered Species Act, it is important to understand how their habitat may be affected. These habitat components directly affect growth, survival, and reproduction of this community. For the five river reaches upstream from Sioux City, this module determines how well monthly depth and velocity distributions under the alternatives match those that were available prior to channel modifications and changed flow patterns. This approach assumes that historic distributions of these two components represent optimal conditions for all species in this community. Depth and velocity distributions under current channel conditions were examined by experienced biologists to determine optimal flows in each of the 12 months for four river reaches downstream from Sioux City. The monthly values were summed to obtain the annual values for each of the nine reaches modeled.

System operation has a direct effect on the acreage of specific wetland and riparian habitat types through changes in reservoir and river water levels. The acreage of each wetland and riparian habitat type at each elevation was mapped within representative sites in each reservoir and river reach in 1990. These data were used as the initial elevation distribution of habitat types for the module. Successional "rules" were developed for each habitat type that described the hydrologic conditions that would cause a change from one type to another. Stage/discharge relationships for each site were developed to determine the water elevation for each month of the period of record from the LRS Model output. These stages were applied to the previous years's elevation distribution data to determine the "new" elevation distribution of habitat types at each site. A final step was to categorize the various habitat types as either wetland or riparian. Summing the resulting acreages resulted in the acreage of wetland or riparian habitat for each year of the period of record under each alternative. The changes in the modeled sites provided insight to the potential changes in the various Missouri River reaches.

Nesting habitat of the interior least tern and the piping plover consists of unvegetated river sandbars. The amount of this habitat was estimated for the river reaches downstream from Fort Peck Lake, Lake Sakakawea, Lake Francis Case, and Lewis and Clark Lake. The initial amount of habitat in the module was that measured for differing flows in 1991. Two steps were incorporated into the module. The first consisted of a methodology similar to the wetland and riparian habitat methodology plus a scouring computation for high flows that depicted how vegetation cover may change on the islands (and increase or decrease bare sand habitat). The second accounted for differing sizes of the islands depending on the river flow, or stages in the months of June through August (nesting season) of each year. Since 60 consecutive days of available habitat are required to nest, hatch, and fledged these birds, the minimum amount of habitat in the June-July and the July-August periods were compared to compute the minimum amount of habitat available in each year of the period of record.

The historic properties module is based on how many known historic sites on Fort Peck Lake and Lakes Sakakawea and Oahe may be subjected to wave erosion on a monthly time step

over the period of record. Sites are assumed to be subjected to erosion when they are 3 feet below or 5 feet above the end-of-month reservoir level identified by the LRS Model. These monthly values were converted mathematically so that the lower the number of sites potentially eroded, the higher the index value computed by the module.

EVALUATION OF IMPACTS

Once the two impacts models were developed, impacts could be computed by running the two, user friendly models on LRS Model outputs. The outputs from each of the two models can be looked at in various levels of details. For each of the uses and for some of the environmental resources, a value was computed for each month in the period of analysis. One could look at a value for a specific month, the average of a portion or all of the years for that month, or any other basis using the data from all of the years modeled. In the case for some of the resource categories, values were computed for only some of the months in each year (e.g., amount of habitat meeting certain water quality criteria for the riverine cold and warm fish value functions) or only one value per year was computed (e.g. amount of wetland habitat). In these cases, the number of outputs were more limited (i.e., you could not show a value for a given month in the case of the wetland habitat). In every case, an average annual value could be determined for all or a portion of the period modeled. Examples of Missouri River output for the entire 96-year period of analysis modeled for the Draft EIS released in July 1994 are shown in the following tables. The first alternative is the current water control plan (CWCP), and the second one is the preferred alternative (PA) from the Draft EIS. From these tables, one can see the variety of units for the environmental resources and the changes resulting when a plan dramatically different from the current water control plan is modeled.

Average Annual National Economic Development Value ($ millions)						
Alt.	Flood Control	Navigation	Hydropower	Water Supply	Recreation	Total
CWCP	44.4	17.7	619.8	546.2	75.7	1,304
PA	42.6	15.0	620.6	546.7	77.7	1,303

Average Annual Values for Fishery Resources					
Alt.	Res. Young Fish Prod. (Index)	Reservoir Coldwater (MAF)	River Coldwater (Miles)	River Warmwater (Miles)	River Physical Hab. (Index)
CWCP	1.96	9.9	187	49.4	59.0
PA	2.03	10.6	187	58.8	64.1

Average Annual Environmental Values for Non-Fishery Resources				
Alt.	Wetland Habitat (1000 acres)	Riparian Habitat (1000 acres)	Tern and Plover Habitat (Acres)	Historic Properties (Index)
CWCP	155	108	432	4,689
PA	166	96	587	4,484

CURRENT EFFORTS TO ADDRESS PUBLIC CONCERNS

Review comments on the Draft EIS released to the public in July 1994 identified the need for additional technical analyses to better address potential impacts of the preferred alternative in the areas of interior drainage and ground water. As discussed earlier, more detailed analyses of these two areas surfaced the need for a hydrologic model that could identify potential changes in flow on a daily time step instead of a monthly time step. Thus, the Daily Flow Model development began in earnest. Even though many of the existing analyses will be basically the same for future study activities, efforts are currently underway to update value functions for some of the modules or to modify the procedure to prepare the value functions for others. The majority of the future analyses will be based on the monthly time step for which the DF Model can provide the required data.

In normal inflow periods, the preferred alternative would provide increases in spring flows in the lower Missouri River. These flow increases would have the potential to impede interior drainage from leveed areas in this reach. After examining potential analysis options, the existing Interior Flood Hydrology model by the Hydrologic Engineering Center (HEC-IFH) was selected as the analytical tool to identify differences in the amount of flooding that could occur behind selected levee units. To evaluate potential economic impacts of this flooding, another HEC model was selected and adapted -- the Project Benefits Analysis (HEC-PBA) model. These two models will be teamed with the DF Model to analyze the day-to-day variations in river flow and the impacts of these flows on interior drainage. A daily time step is required because the spring increases in flow can be reduced in time to limit, if not eliminate, increases in interior drainage incidents.

Ground-water concerns have also been expressed that led to an effort to determine potential differences in impacts for a change to another alternative, especially one with increases in spring service levels. The ground-water economic analysis will be conducted by linking DF Model river flow daily outputs for the lower Missouri River to a series of ground-water models (one for each area analyzed) based on the U.S. Geological Survey MODFLOW model. Expected outputs from this model will be converted to areas of shallow ground-water levels that are expected to adversely impact agricultural use of the lands adjacent to the river. Again, an adaptation of the HEC-PBA model will be used to depict the economic impacts of ground-water changes among the alternatives analyzed. (Note: An adaptation of the HEC-PBA model is also going to be used for the flood control economics.)

CONCLUSIONS

Throughout the Master Manual study, it was readily apparent that the general public has a desire to be much more involved and educated regarding river management than has been the case historically. It is imperative that information provided be thorough and yet easily understood. The selection of the basic study methodology must be basic enough that the public has can understand it and so that it can have a high level of trust in the results obtained from the study process. As a key component to the accomplishment of the required trust, detailed development of the components of the methodology must be thoroughly coordinated with the public, whether it be other Federal agencies, state agencies, special interest groups, or interest individuals. Public meetings and workshops are essential in informing the public of study results. Of equal importance, is adequately involving the public during scoping meetings to fully understand the needs of the affected publics.

Even though extensive efforts were undertaken to involve the public, especially those with considerable technical expertise, the need for revision to the study methodology may surface to better meet the concerns of the public as it becomes more involved in the study. The current efforts underway as part of the Master Manual study are proof that the public is able to grasp extremely technical material and provide constructive input. Throughout the Master Manual study, team members were exploring existing new technology or developing new technology to meet its requirements as it strove to better understand and depict the potential impacts of changes in system operations. New technology will always be needed to meet the growing requirements of the study teams and the public.

COLUMBIA RIVER SYSTEM OPERATION REVIEW

by

Ray Jaren[1]

INTRODUCTION

The Columbia River Basin has been undergoing multiple purpose development of its water resources since the mid 1930s. Early "308" studies began the process with development of the Bonneville and Grand Coulee projects. Later review studies of the basin resulted in addition of more projects to the system. Most of the projects were constructed from the 1950s through the 1970s. In the early 1960s a treaty was negotiated between Canada and the United States which called for construction of projects in both countries which more than doubled the total storage in the system from about 18 million acre-feet (MAF) to about 44 MAF. Principal purposes of the Federal projects are for power, flood control, navigation and irrigation. Other uses include recreation, fish and wildlife, and water supply. By the 1970s most of the practical storage and run-of-river project sites had been completed. At the same time it was becoming increasingly clear that the limit of the resources was being approached and that the river system was fully spoken for by the various user and interest groups.

STARTING THE SOR

By 1989 the Corps had completed all interim reports for its Columbia River and Tributaries Review Study and was deliberating a proposal for a review of the operation and use of the existing system of Federal water resources projects. Coordination with Bonneville Power Administration and the Bureau of Reclamation in the fall of 1989 led to a consensus among the three agencies to consider a three agency review of the system. Preliminary scoping and issue examination by the three agencies led to an agreement in January 1990 for the three agencies to jointly conduct the Columbia River System Operation Review (SOR).

SCOPING

A first order of business for the SOR Team was to examine in more detail what the scope of such a review could and should entail. Very early it was determined that not all of the projects in the system need be included directly. Of the 120 or more water resources projects in the system, about 30 are federally owned, and of those, 14 are considered of such major size and scope as to significantly effect or govern system operations.

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The initial scope of the study was thus limited to those 14 projects. They include 12 Corps and 2 Reclamation projects as shown on the Basin Map, Figure 1-1. Corps projects included the four lower Columbia and four lower Snake run-of-the-river projects and Chief Joseph as well as three Corps storage projects, Libby, Dworshak, and Albeni Falls. Reclamation projects included Grand Coulee and Hungry Horse.

The next consideration for scoping was geography. Because of the international boundary, the SOR would need to be coordinated with Canada and British Columbia. Canadian interests were invited to participate in the SOR and sent representatives to early meetings. They eventually decided to conduct a similar study of projects within their own borders.

Another issue receiving much debate was whether to include the Upper Snake River Basin in the SOR. Eventually the Corps and Bonneville deferred to Reclamation arguments that the snake was better studied apart from the SOR. Later, in public involvement, this issue was raised repeatedly by others, most often that the snake should have been included. Recently, Reclamation began a five year Snake River Water Resources Review of this portion of the Columbia Basin.

SOR PURPOSES

During scoping, legal and institutional mandates and public concerns were examined to develop statements of purpose for the SOR:

Mandates to:

- Act within the authorities granted to the agencies under existing statutes
- Satisfy existing contracts
- Identify areas where new statutory authority may be needed
- Provide public access to the Columbia River System Operating Strategy (SOS) and future decisions associated with it
- Create a technical data base for system operating decisions
- Comply with environmental laws and regulations
- Satisfy Native American treaty rights and obligations for natural and cultural resources

Public concerns to provide:

- An economic, reliable, and environmentally sound power system
- An adequate supply of irrigation, municipal, and industrial water
- Public safety through an economic and dependable flood control system
- A waterborne transportation capability
- Equitable treatment of fish and wildlife
- Opportunities for recreation at lakes, reservoirs, and rivers
- Protection and preservation of threatened, endangered, and sensitive species
- Protection and preservation of cultural resources
- Protection and enhancement of socioeconomic well-being
- Protection and enhancement of environmental quality

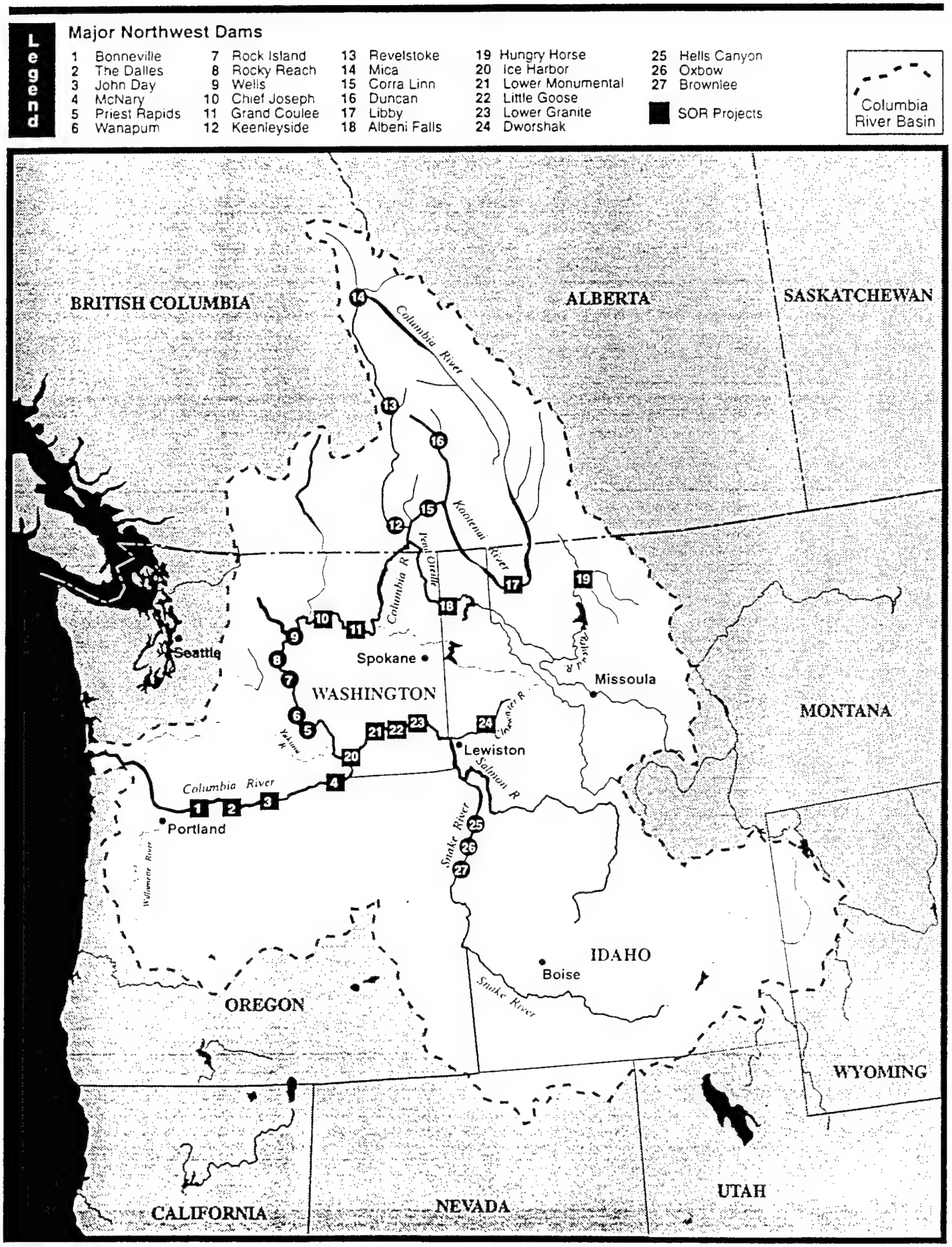

Figure 1-1. Columbia River Basin

PROPOSED ACTIONS

Development of an updated system operation strategy has been a principal focus of the SOR, however there are three other actions integral to the study:

- the Columbia River Regional Forum (The Forum),
- the Pacific Northwest Coordination Agreement (PNCA),
- the Canadian Entitlement Allocation Agreements (CEAA).

The Forum was envisioned as a means to conduct periodic review and update of the SOS and to provide others a role in shaping the decisions on system operations. Because of their coming expiration the PNCA and CEAA were part of the need for the SOR as it provides the environmental analysis of river operation strategies needed before the operating agencies can sign updated versions of these important multi-party Columbia Basin pacts. Negotiations for the PNCA and CEAA have been conducted in parallel with the SOR and are still underway but nearing completion.

ORGANIZATION

Organization of the SOR Interagency Team was fashioned to provide a workgroup for each project purpose or river use area. The work groups included participants from each of the three lead agencies and from other agencies and groups as well as the general public. In all there were ten functional workgroups. In addition management and executive groups were formed to oversee the SOR process. Organization of the SOR is shown in Figure 1-2.

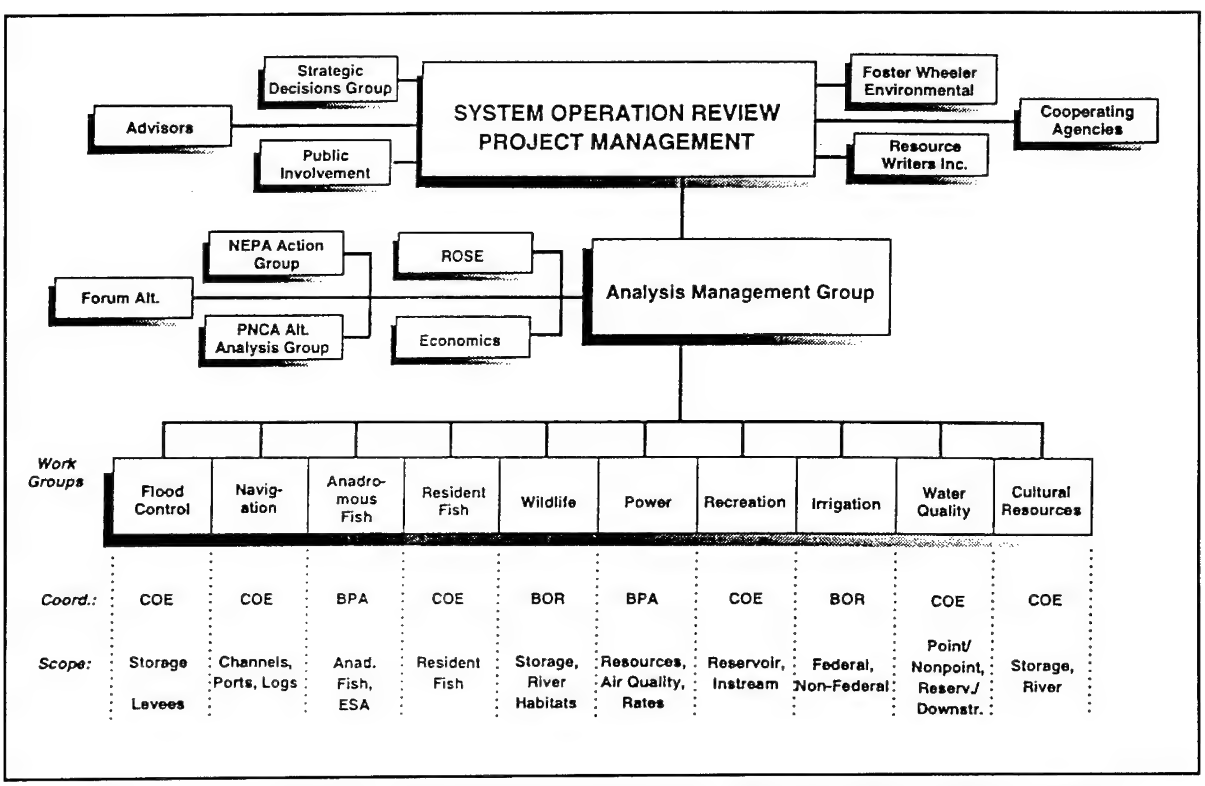

Figure 1-2. Columbia River System Operation Review Organization Chart

SCHEDULE

At the outset, completion of the SOR was thought to be possible in three years. Within the first year, however, the schedule was lengthened to four years. Later, feeling some pressures to complete consistent with PNCA, and CEAA schedules, it was again considered to accelerate the schedule to three years. This push did not prevail and ultimately it took six years from the decision to proceed to putting the Final EIS on the street in January 1996.

FUNDING

The costs of the SOR were born by each of the three agencies contributing budgeted funds, while emphasizing contributions of expertise best suited to the missions of each. Reclamation and the Corps assumed a greater part of the technical effort while Bonneville contributed more to the administrative tasks. Combined cost for the three agencies to conduct the review was about $24 million.

PROCESS

The process used by the SOR Team was based upon the usual step or phasing approach where increasing levels of detail are utilized as an initially large number of potential alternatives are successively screened down to a more manageable number. The initial step for SOR was to assign several workgroups to participate in a pilot effort to explore and develop a specific process and methodology for the full team to use in the screening and detailed phases.

The pilot studies were assisted in the use of decision analysis concepts by outside consultant. A first step was to identify key variables for each river use through the application of decision analysis software to determine the sensitivity of the variables. Graphic displays, termed "tornado diagrams", of the relative importance of each selected variable in determining the modeled output were prepared.

After having identified key variables, workgroups wrote simple spreadsheet models to analyze effects of the alternatives on their river use area. Input to the spreadsheets consisted of data from hydroregulation runs which define monthly flows within river reaches and monthly elevations at storage or run-of-river projects.

For the pilot program and later for screening, flows and elevations were determined using five years of record, representing high, medium, low, and medium high and medium low water years. Only for the detailed evaluations was the complete 50-year period of record used. Hydroregulation models available for use include the Corp's HYSSR model and BPA's Hydrosim model. Both were used at various times during screening as workload and staff availability dictated. Hydrosim was used exclusively for detailed analysis.

During screening 90 alternative ways of operating the system were identified and evaluated. Many of those fell into groupings with similar objectives or characteristics. Several of the best alternatives were selected from those groups and presented to the public as candidate

strategies. A total of 21 alternatives were evaluated in detail for the draft EIS and of those 13 survived for inclusion in the Final EIS.

PUBLIC INVOLVEMENT

As shown in the organization chart the SOR included a Public Involvement work group. The work group focused on overall strategy and needs for public involvement. The group identified points in time during the study at which public information events and publications should be planned for and performed most of the work to set up for those actions.

Twenty issues of a newsletter "Streamline" were published about quarterly to keep the public informed of SOR progress and status. Several special publications were prepared as public educational materials on special topics which were deemed important, complex, and not well understood by other agencies, groups, and the public. The topics included, how the system is operated, short term operations, the PNCA, and how models are used in planning the system.

Three public meeting sessions and one public information session were conducted at more than a dozen locations throughout the region for the various phases of the study. Dual slide/sound and video shows were written and produced by the team for use at the meetings to provide concise, consistent, and convenient information to promote discussion of issues. Some of those materials are still in use to provide information to the general public. More than 800 persons attended the various meetings throughout the region.

ISSUES

Issues emerging from agencies and the public were wide ranging but tended to cluster into local or regional categories:

- Impacts to the local economy from existing or changed system operations
- Effects of operations on lake levels, fishing, and tourism
- Resident fish and wildlife versus anadromous fish
- Support for traditional system uses
- Salmon recovery versus economic uses of the system
- Removal of dams
- Juvenile fish transportation
- Frustration with ESA
- Uncertainty of benefits to anadromous fish
- Certainty of impacts to current uses
- Reliance of northwest economy on multi-river system
- Impact of drawdowns

STAKEHOLDERS

A variety of interests participated in the SOR. Some of the more active participants included environmental groups, irrigators, towboat and barge companies, grain growers, utilities, Indian tribes, recreational interests, and states.

LITIGATION

During the SOR more than a dozen law suits were filed in the region, mostly pertaining to the endangered species and how the system is operated. One suit dealt directly with the SOR and directed that a closer, hard look be taken of the transportation of juvenile fish downstream by barge. The SOR Team reevaluated juvenile transportation and added an additional appendix to the Draft EIS. Further litigation is pending and expected.

ENDANGERED SPECIES ACT

Three months after beginning the SOR, endangered species petitions were filed with NMFS. Shortly thereafter, a Salmon Summit was convened by Senator Mark Hatfield of Oregon. He urged regional interests to work together to achieve recovery of the petitioned species so as to avoid undo federal intervention in regional decisions. The Salmon Summit resulted in the examination of issues and education of the various interests in the region as to the facts and circumstances of the listed species and developed a number of recovery measures to consider. The SOR and the recovery team both benefited from the information flowing from the summit.

A year later the petitioned species were listed as endangered and threatened. This formal listing gave significant new legal status to the species which all involved agencies were obliged to respect and consider. For the SOR it further deflected its already altered course toward recovery of salmon and away from the system balancing originally sought. This course has remained a part of the SOR to its conclusion.

COMMENT RESPONSE

Comments from the Draft EIS were incorporated in the final alternatives as appropriate. Responses to comments were prepared for inclusion in an appendix to the FEIS. More than 200 written comments were received.

FINAL ALTERNATIVES

The most significant change to the final set of alternatives, listed below, resulting from public review of the draft EIS was the addition of a permanent river level drawdown of the lower snake run-of-river projects. Compared to the draft alternative calling for part year drawdown, this would have much-reduced costs and not inflict the alternating adverse impacts of annual drawdown and refill. Other changes in the final alternatives involved reorganization of the presentation of flow alternatives. The draft EIS place holder for the preferred alternative became occupied by the NMFS biological opinion. The effect of the strategies on river uses is shown in the chart following the list of alternatives.

- **SOS 1a - Pre-ESA Operations:** This is the way the system was operated from about 1983 through 1990-91, prior to the listing of salmon species under the ESA. Elements of an alternative recommended by the Columbia River Alliance, Recover 1, were included.

- **SOS 1b - Optimum Load-Following Operation:** This option would maximize system benefits for the traditional uses of the system, power generation, flood control, and navigation. It is the way the system was operated prior to the Northwest Power Planning and Conservation Act of 1980.
- **SOS 2c - Current Operation/No Action:** This alternative calls for operations consistent with the Corps of Engineers' 1993 Supplemental EIS. It is similar to operations in 1992 and 1993, after three salmon species were listed under the ESA.
- **SOS 2d - 1994-98 Biological Opinion:** New system operations have been developed since SOS 2c was formulated. Operations are those carried out by the agencies after consultation with NMFS in 1994; it is closest to the way the system is currently being run.
- **SOS 4c - Stable Storage Project Operation:** Specific monthly elevation targets would be used year-round to improve conditions at the major Federal storage projects for recreation and resident fish and wildlife. In response to public comments , this alternative includes minimum elevation levels, known as Integrated Rule Curves (IRCs) for Libby and Hungry Horse Reservoirs.
- **SOS 5b - Natural River Operation:** The four lower Snake River projects would be drawn down to near riverbed levels for four and one-half months during the spring/summer salmon migration period. Construction of new low-level outlets would be required to allow water to bypass the dam, powerhouse, and spillway.
- **SOS 5c - Permanent Natural River Operation:** The four lower Snake River projects would be drawn down to near riverbed levels year-round.
- **SOS 6b - Fixed Drawdown:** The four lower Snake River projects would be drawn down to near spillway crest for four and one-half months during the spring /summer salmon migration period.
- **SOS 6d - Lower Granite Drawdown:** This alternative would draw down Lower Granite to near spillway crest for four and one-half months.
- **SOS 9a - Detailed Fishery Operating Plan (DFOP):** This operation was recommended by the region's fish agencies and tribes. It would establish flow targets at Lower Granite and The Dalles, draw down lower Snake River projects to near spillway crest for four and one-half months, specify spill levels at run-of-river projects, and eliminate fish transportation.
- **SOS 9b - Adaptive Management:** This modification of DFOP would establish flow targets at McNary and Lower Granite, specify maximum water releases from upstream projects, draw down lower Snake River projects to minimum operating pool, draw down John Day to minimum irrigation pool, and specify spill levels at run-of-river projects.
- **SOS 9c - Balanced Impacts Operation:** This alternative was originally recommended by the State of Idaho, which subsequently withdrew its support. It would draw down the four lower Snake River projects to near spillway crest for about two months during the spring salmon migration period. It also includes flow augmentation at 1994-98 Biological Opinion levels, IRCs at Libby and Hungry Horse, and a higher winter operating elevation at Albeni Falls.
- **SOS PA - Preferred Alternative**

How the Strategies Would Affect River Uses

	SOS 1	SOS 2	SOS 4	SOS 5	SOS 6	SOS 9	PA
Anadadromous Fish	Moderate passage survival and adult escapement; slight differences from existing conditions	Survival rates in the middle range of all alternatives; with transport, juvenile survival is high	Survival about the same as SOS 2	Highest in-river survival for Snake River stocks; for other stocks, similar to existing conditions	In-river survival for Snake River stocks varies greatly depending on assumptions	Some of the highest and lowest in-river survival depending on SOS option and stock	In-river survival for Snake River stocks similar to SOS 2; in-river survival for other stocks in the mid to upper range
Resident Fish	Variable conditions among reservoirs and species; pool fluctuations and failure to refill impact productivity	Variable conditions among reservoirs and species; pool fluctuations and failure to refill impact productivity	Best SOS for resident fish; improved productivity at storage projects	Generally poor ; some reservoirs have improved conditions under SOS 5c	Impacts generally the same as SOS 5, but not as severe; conditions worse at Lower Granite and John Day	Some of the best and worst impacts of all SOSs; 9a is generally worse, 9b is good, 9c is mixed	Conditions better at Lake Roosevelt, Hungry Horse, Lower Granite, and John Day; worse at Dworshak, sturgeon improved
Wildlife	Resources largely unchanged from current conditions, continuation of downward trends	Long-term downward trends to resources; slight impacts at John Day due to lower reservoir levels	Moderate to significant increases in wildlife habitat at Lake Pend Oreille, Libby, Hungry Horse, and Grand Coulee	Severe reductions in wildlife habitat at lower Snake and John Day projects	Wildlife habitat impacts similar to SOS 5; 6d limits impacts to Lower Granite	Significant impacts to John Day under 9a and 9c; 9b similar to SOS 4 with no benefit at Libby and Hungry Horse	Impacts at John Day similar to SOS 5b; stable levels allow some restoration of habitat; some impacts at Grand Coulee
Power	Energy production and load shaping maximized; 0 6-1 1% rate decrease	Annual generation costs the lowest of all SOSs except SOS 1; up to 0.4% rate increase	Flows and generation needs mismatched; 1.3% rate increase	Eliminates system load shaping capability; reduces average annual energy generation; 2.5-2.8% rate increase	Generation effects similar to SOS 5; generation costs slightly more than SOS 2c; 0.3-0.9% rate increase	Hydropower generation reduced due to high spill and drawdowns; 2.5-4.0% rate increase	Increased water storage in fall and winter and increased spill mismatches flow and generation needs, 2 0% rate increase
Flood Control	Flooding risk unchanged from current conditions	Flooding risk unchanged from current conditions; expected annual average flood damage costs are $3.3 million	Increased risk at Bonners Ferry, the upper Columbia, and Clearwater reaches; average annual flood damage costs increase $0.4 million over SOS 2c	Flood risk in all areas similar to SOS 2	Flood risk in all areas similar to SOS 2	Highest flood risk primarily in upper Columbia; average annual flood damage ranges from $0.03 to $0.5 million more than SOS 2c	Upper Columbia flood damages increase $0 2 million over SOS 2c
Navigation	Normal conditions for shallow draft navigation and reduced costs for Dworshak log transport, net decrease $0 1 million compared to SOS 2c	Shorter Dworshak log transport operating season; total annual cost for navigation is $414 4 million	Longer Dworshak log transport operating season; net decrease $0.2 million compared to SOS 2c	No shallow draft navigation on the lower Snake River for 7 months or permanently; net increase $14 to $38 million compared to SOS 2c	No shallow draft navigation on the lower Snake River or Lower Granite for 6 months; net increase $2 to $12 million compared to SOS 2c	No shallow draft navigation on the lower Snake for 3 or 6 months; net increase up to $12 million compared to SOS 2c	Normal operations for navigation, shorter Dworshak log transport season; net increase $0 1 million compared to SOS 2c
Irrigation, Municipal and Industrial Water Supply	Minor increase in pumping costs at Grand Coulee of $9,000 over SOS 2c	All irrigation needs served	Minor decrease in pump-ing costs at Grand Coulee of $18,400 over SOS 2c	Drawdowns at John Day and Ice Harbor require pump modifications and increase pumping costs by about $3.3-4.5 million	Drawdowns at John Day and Ice Harbor require pump modifications and increase pumping costs by about $1.4-2.6 million	Similar impacts to SOS 6 at Ice Harbor and John Day; minor increase in pumping costs at Grand Coulee up to $34,900	Minor savings in pumping costs at Grand Coulee,$1 5 million increase at John Day, $4 3 million increase for M&I
Cultural Resources	Ongoing shoreline erosion and exposure at same rate as current conditions	Ongoing shoreline erosion and exposure at same rate as current conditions	High rates of shoreline erosion at storage projects; decrease in exposure due to high pools	Dramatic increase in exposure at lower Snake River projects; less shoreline erosion at these projects	Similar to SOS 5 but less dramatic	Increased shoreline erosion and exposure due to drawdown; increased bank sloughing due to flow augmentation	Little overall change from current conditions, site exposure increases at Dworshak and John Day
Recreation	Annual benefits could increase up to $7.9 million under SOS lb	Annual average recreation benefit is $315 million	Annual benefits could increase $4 2 million	Annual benefits could decrease between $66 and $90 million	Annual benefits could decrease up to $40 million	Annual benefits could decrease $35 to $97 million depending on option	Annual benefits decrease by $26 million
Water Quality	Slight decrease in water temperature but increase in total dissolved gas in lower Snake River	Similar to SOS 1 but slight increase in water temperature; decrease in total dissolved gas	Similar to SOS 2 with slightly lower dissolved gas in lower Columbia	Maximum silt concentrations; nearly all excessive dissolved gas eliminated in lower Snake	Major sediment transport similar to SOS 5; dissolved gas and water temperature similar to SOS 2	Highest impacts due to water temperature and total dissolved gas supersaturation	Similar to SOS 2 except high total dissolved gas in the lower Columbia
Change In Total Annual System Costs*	-$42 to -$80 million	$29 million, but SOS 2c equals 0 (no action alt.)	$81 million	$266 to $336 million	$78 to $145 million	$233 to $400 million	$164 million

*Includes capital expenditures to modify existing dams

1995 BIOLOGICAL OPINIONS AND SOR PREFERRED ALTERNATIVE

The NMFS and USFWLS Biological Opinions issued in March 1995 form the basis for the SOR Preferred Alternative. The intent of the BO is to support the recovery of ESA-listed fish. This is to be accomplished by storing water in reservoirs during the fall and winter to meet spring and summer flow targets and using maximum summer draft limits to minimize detrimental effects on other natural resources, while still providing flood protection and a reasonable level of power generation.

Development of a BO begins with the operating agencies developing a description of a proposed plan of operation or action in the form of a Biological Assessment (BA). The BA contains information on the effects of the plan or operation on project conditions such as water elevations, flows, durations, frequencies, and other information needed by the resource agency to render an opinion whether and how the proposed action or plan will affect the listed species.

FINAL EIS

The final EIS was distributed to agencies and the public in January 1996. In total it comprises more than 6,000 pages and includes a Summary, Main Report, and 20 Appendices. It had been planned to make a CD-ROM version available but the profusion of software used for the documents made this unworkable in meeting the schedule for release of the printed version. Efforts are still underway to convert the Summary and Main Report to CD-ROM. Copies of the reports are available by calling the SOR document request line at 1-800-622-4519.

RECORDS OF DECISION

Completion of an EIS does not constitute the taking of a federal action or even of making a federal decision. This is accomplished through the preparation and signing of a Record of Decision (ROD) by an agency head. In a ROD the agency reflects all relevant information from existing and newly developed NEPA process results and any other relevant information emerging subsequent to completion of the NEPA process. For the Columbia River system the agencies signed RODs in March 1995 to permit continued operation of the system but under the newly released BO. The agencies are continuing to operate under the 1995 RODs and will continue to do so until such time as significant departure from the BO are needed. At that time new RODs will be prepared to reflect those departures and will incorporate new information.

LIFE AFTER SOR

As of January 1996 the SOR is officially complete. However, some related work will continue into the next several years. This includes four items at this time, a review of Columbia Basin flood control storage with a view to provision of additional flows for anadromous fish, winter drawup of Albeni Falls reservoir for Kokanee spawning, integrated rule curves for Libby reservoir in Montana, and implementation of cultural resources protection in coordination with native American tribes.

APPLICATION OF A PRESCRIPTIVE RESERVOIR MODEL (HEC-PRM) TO THE COLUMBIA RIVER SYSTEM

by

Michael W. Burnham and Darryl W. Davis[1]

INTRODUCTION

The Columbia River basin covers 259,000 sq. mi. in Washington, Montana, Oregon, Idaho, Wyoming, Nevada, Utah, USA; and in British Columbia, Canada, as shown in Figure 1. The basin includes more than 250 reservoirs and 100 hydroelectric projects on the Columbia, Snake, Kootenai, Clearwater, and Pend Oreille Rivers and their tributaries. About 120 of these projects comprise the coordinated Columbia River Reservoir System. The US Army Corps of Engineers (USACE) and the US Bureau of Reclamation (BuRec) operate the system for power generation, flood control, anadromous-fish, navigation, and irrigation. Other uses include water supply, recreation and fish and wildlife. The Bonneville Power Administration (BPA) coordinates the power operation and markets the power produced. (BPA, USACE, BuRec, 1990)

The three federal agencies (USACE, BuRec, and BPA) began a joint comprehensive review of system operation in 1990 (SOR) (USACE, 1990a and 1990b). The USACE North Pacific Division asked the Hydrologic Engineering Center (HEC) to develop a system analysis model for the system. The HEC-PRM (prescriptive reservoir model) was selected. HEC-PRM is a generalized network-flow programming model designed for study of multipurpose, multi-reservoir systems.

PRESCRIPTIVE RESERVOIR MODEL

The USACE and others traditionally use descriptive tools to determine reservoir system performance for specified operating rules. Descriptive models perform reservoir mass continuity, channel mass continuity, and hydropower production for specified inflows and system physical configuration, characteristics, and in accordance with fixed reservoir storage-release rules. Alternative physical features and/or operation rules are then studied by successively altering the appropriate features and performing simulations.

A prescriptive model differs in that system operation is performed in response to goals measured by an objective function. HEC-PRM represents a reservoir system as a network consisting of nodes interconnected by arcs. Reservoirs and system demand and supply points are represented as nodes. Conveyance and storage facilities are represented as arcs. This network representation of the reservoir-system operation problem is similar to that used by Sigvaldason (1976), Martin (1982), Sabet, et al. (1985), and Chung, et al. (1989).

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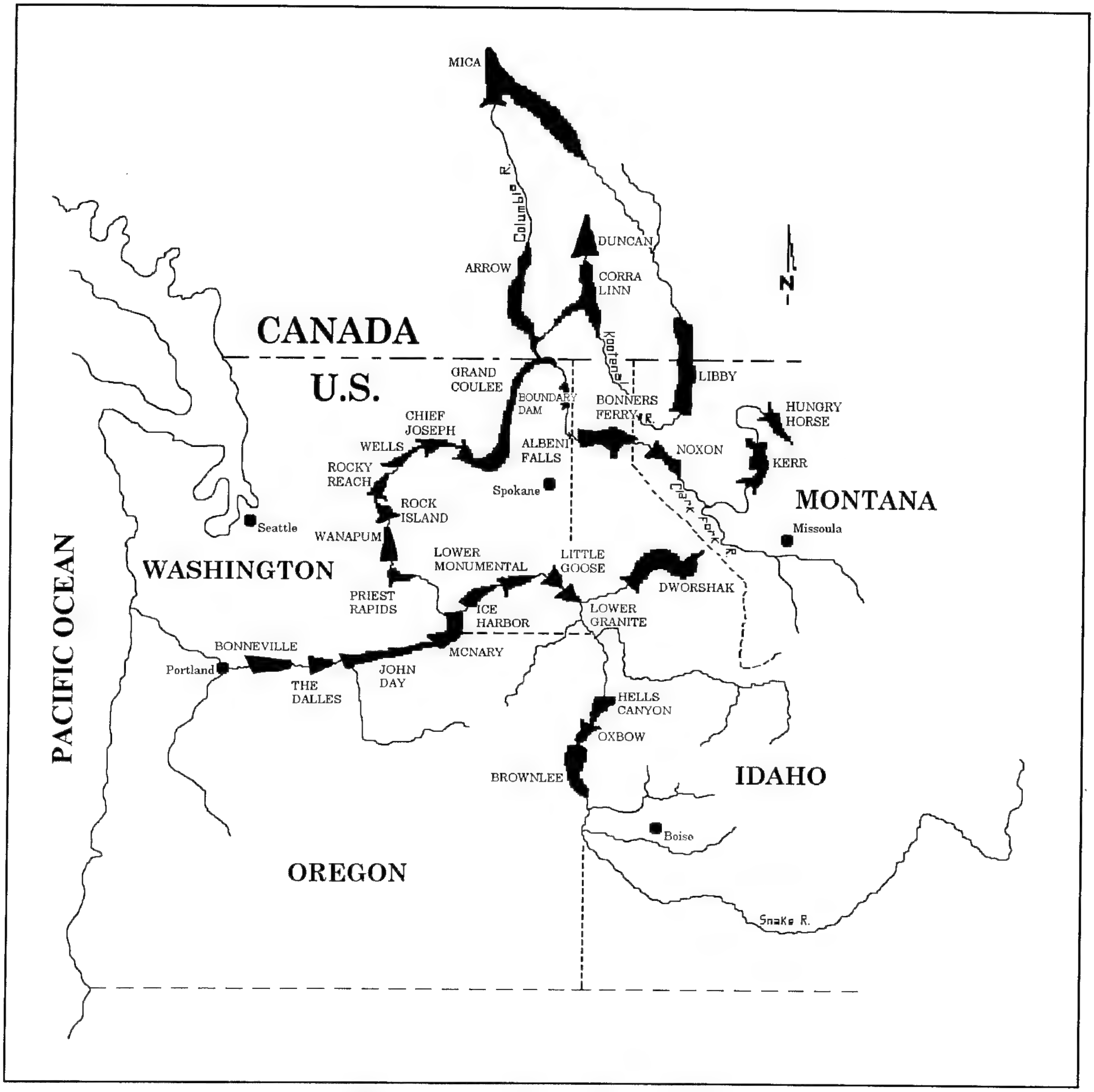

Figure 1. Columbia River System

Operation Goals and Constraints. The HEC-PRM operating scheme is accomplished using constraints on flow, release, or storage, and by assigning penalties for too much or too little flow, release, or storage. Constraints define an inviolable upper and lower bound on flow, release, or storage at any location and time. Penalty functions may be either cost-based or non-cost-based. Cost-based functions show the loss in economic value as flow, release, or storage deviates from the optimum flow (USACE, 1993). Cost-based penalty functions can typically be developed for urban and agricultural flooding, water supply, recreation, hydropower, and navigation. Non-cost-based penalty functions are needed to represent goals of system operation

not quantifiable in economic terms. Penalty functions for individual purposes at various locations may vary over time. A summed convex piecewise-linear representation is used to approximate the combined function.

Mathematical Programming Formulation. The mathematical-programming model is formed when the network model, constraints, and penalty functions are combined.

HEC-PRM employs a network-flow programming algorithm to lead to the solution. This is a special case linear programming (LP) solution method. Determining the optimal water allocation in systems with hydropower requires a slight modification to the solution procedure. Hydroelectric energy and thus penalty functions are not simple linear equations. Instead they are functions of flow and head (which is related to storage). To find the optimal-flow allocation in a system with hydropower, HEC-PRM uses a successive LP algorithm similar to those proposed by Grygier and Stedinger (1985), Martin (1982), and Reznicek and Simonovic (1990). HEC-PRM is described in detail in USACE, (1993).

PRESENT SYSTEM OPERATION

The Columbia River reservoir system has about 37,000,000 acre-feet of effective storage for mainstream control. This volume represents about 30 percent of the average annual runoff at The Dalles. Reservoirs east of the Cascades, the subject herein, are held as full as possible during the summer to enhance recreation and water conservation uses. Some release occurs during this period for irrigation, water supply, and hydropower generation.

Drafting of the reservoir system occurs early in the fall to provide winter flood control storage space. During this time, power demand increases and recreational uses decrease. Reservoirs reach their lowest levels in March to early May. Snowmelt typically begins to increase in mid-April and peaks in June. Runoff is stored to refill the reservoirs and regulate downstream flooding.

Operation Rules. Within-year operation rules are developed in accordance with a system master water control plan (USACE, 1990b) at the start of the operation year and are updated (normally monthly) as more information on the snowpack and streamflows become available. The operating year is divided into three seasons. A fixed drawdown period occurs from August through December.

During January through March, a variable drawdown operation occurs guided by runoff forecasts. Reservoirs are lowered to provide flood control space and to generate hydropower. During this period, the system generates as much additional energy as possible while maintaining sufficient storage to meet spring fish flows and to ensure a high likelihood of reservoir refill by summer.

Spring runoff is stored and flood peaks reduced from April through July. Water is released to help juvenile salmon and steelhead migration to the ocean. Operation for flood control and power sales continue as needed. (US Department of Energy, et al. 1991).

Water Control Goals by Purpose. Each project purpose requires specification of its own goals and constraints for system operation. Some purposes require the use of water stored in the reservoirs to augment natural streamflow for hydroelectric power, irrigation, navigation, municipal and industrial use, and fish and wildlife. These operations are performed using rules derived from analysis of historic records and updated seasonally.

HEC-PRM SETUP AND ANALYSIS OVERVIEW

The HEC-PRM model for the Columbia system is shown schematically in Figure 2. Data descriptive of the physical features of the system were assembled and coded, hydrologic data assembled and coded, and system performance goals (represented in the form of penalty functions) developed, composited and coded. The system analysis is performed at a monthly time-step, thus stream routing does not required modeling.

Reservoir storage levels are defined as fixed maximum and minimum limits, except at Corra Linn, Albeni Falls, and Kerr. These reservoirs are described as natural lakes formed by terminal moraines, with release structures located on natural channels some distance downstream from the natural lakes they control. Operation is controlled by limiting outlet capacities and application of high penalties for exceeding the nominal upper storage limit. No limiting outlet capacities are specified for other reservoirs. Canadian storage projects are operated under the provisions of Article XV of the U.S.- Canadian Columbia River Treaty.

Penalty functions were developed for each location/reach and project purpose to reflect operation goals (USACE, 1993b). The developed function locations are summarized in Figure 2. The individual functions were combined and edited to yield the convex piecewise linear penalty functions required for HEC-PRM. Figure 3 is an example of a penalty function that applies at a storage node for the month of April. The example includes a reservoir recreation penalty function and a reservoir storage water supply penalty function. The composite is developed by summing penalties for a given storage. A convex, piecewise-linear approximation of the composite function is developed in the format required for the HEC-PRM analysis.

HEC-PRM is run for an adopted fifty-year period of 1928 - 1978 adjusted to reflect 1980 basin conditions (Columbia River Water Management Group, Depletions Task Force, 1983).

The period contains a mix of low and high flow periods that is believed to adequately represent the flow regime. Adoption of this period enables comparisons of management alternatives to be based on a common standard. For model runs, starting and ending storages are specified such that the combined conservation - flood control pool is full. Thus, the overall analysis starts and ends when snowmelt runoff could be expected to have filled available storage.

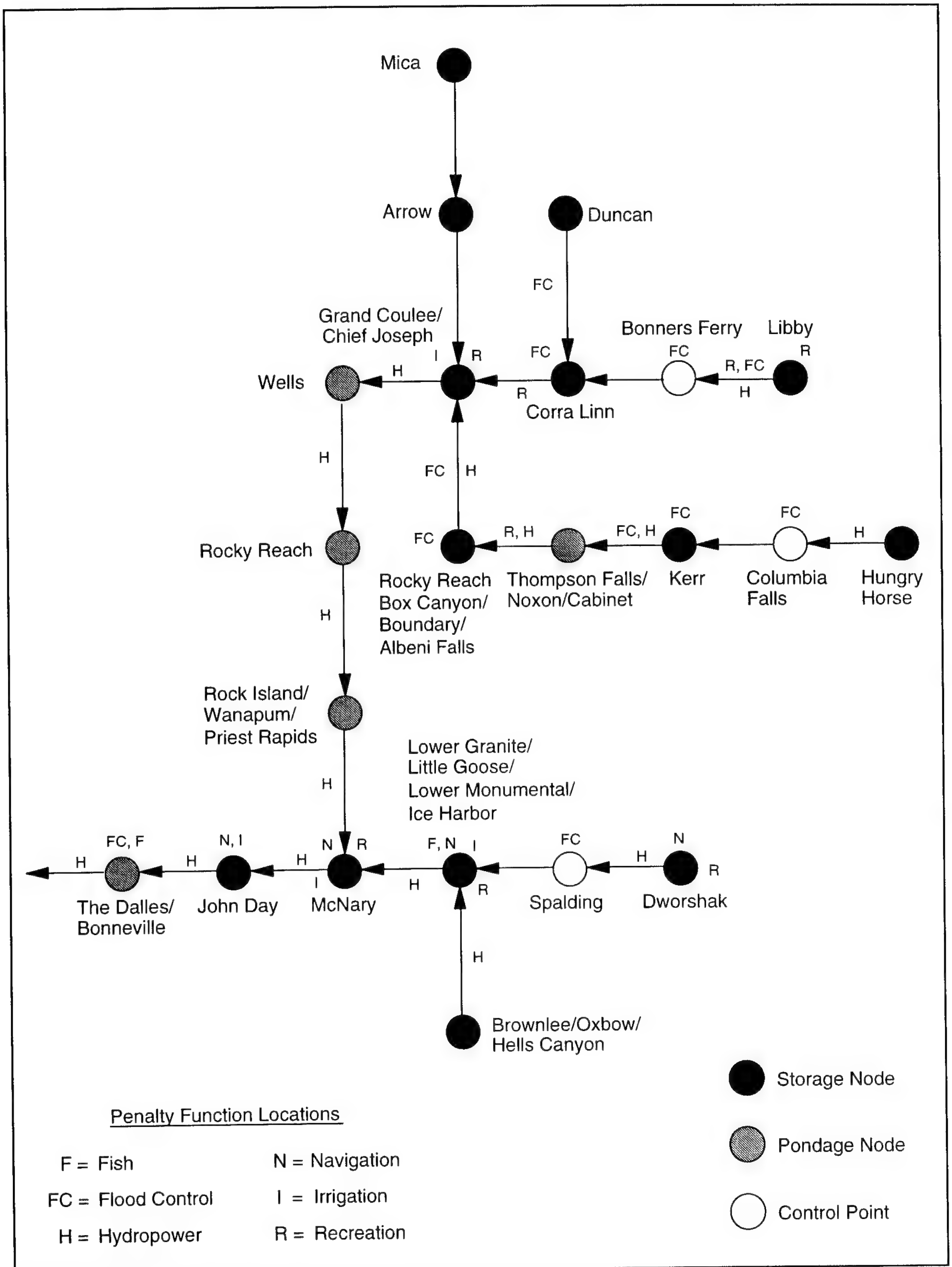

Figure 2. Single-period Network Model of Columbia River System

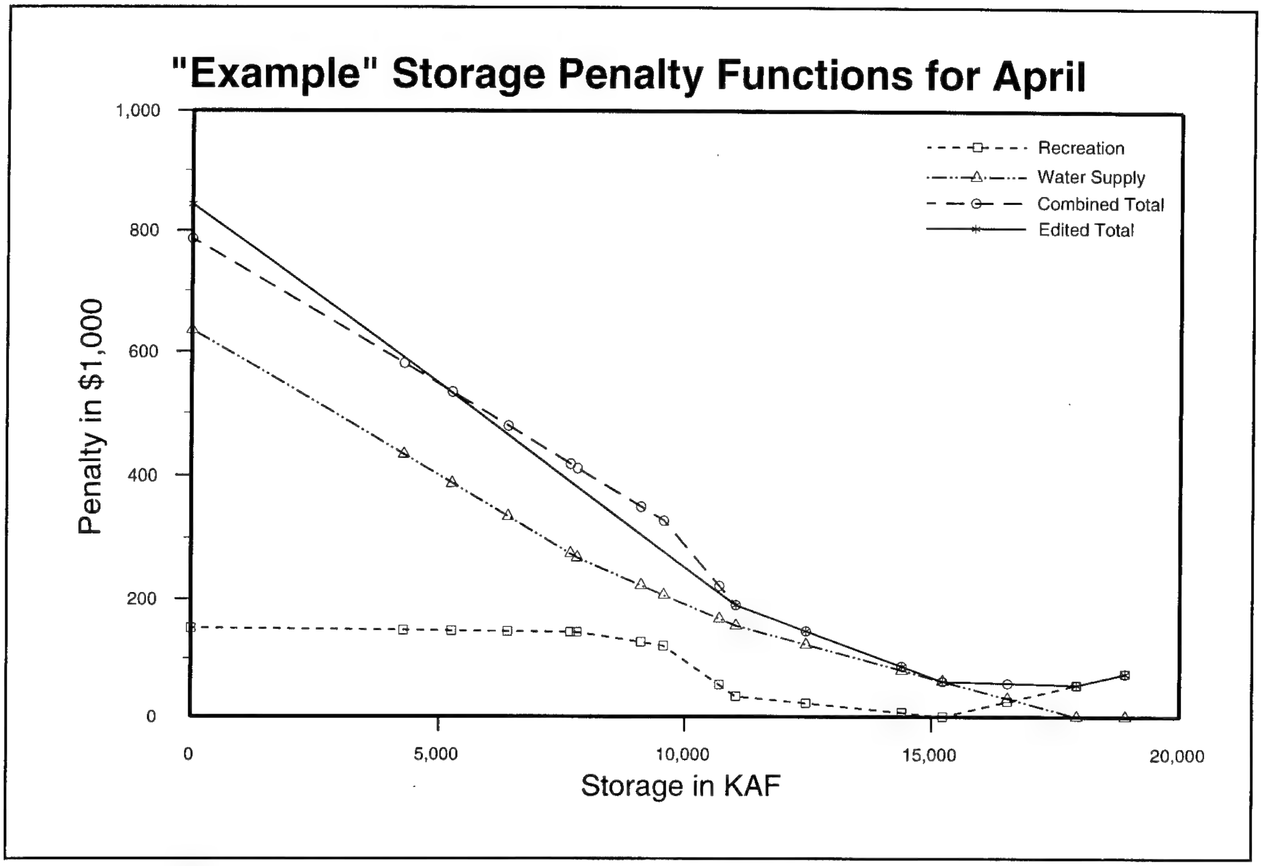

Figure 3. How Penalty Functions are Combined and Approximated

DESCRIPTION OF ALTERNATIVES

The analysis results reported herein are for three alternative operation scenarios: (1) operation with existing objectives and existing Canadian treaty storage; (2) operation with objectives as in (1) but without the hydropower objective; (3) operation with additional Canadian treaty storage. Each alternative is modeled by altering the system penalty functions and/or constraints in the network representation. The base condition for comparison is scenario (1) as reflected in the HEC-PRM analysis results and also as reflected in the results from the USACE Hydro-System Seasonal Regulation (HYSSR) Model (USACE, 1982) run for the same existing conditions as scenario (1). HYSSR is a descriptive simulation program used to perform long-range analysis of the Columbia reservoir system, primarily in connection with hydropower analysis. It is run for the same fifty year period at a monthly time step.

System performance for the alternatives is compared in two ways: performance with current operation rules, as defined by simulation with the HYSSR model and compared to HEC-PRM Alternative 1; and HEC-PRM Alternatives 1, 2, and 3 compared to one another. Alternative 1 is the HEC-PRM model equivalent to the HYSSR model results. Both are intended to reflect existing conditions and system objectives. A perfect match of results was not expected as the models reflect descriptive simulation in the case of HYSSR vs. prescriptive optimization in the case of HEC-PRM.

<u>Alternative 1: Operation with Existing Canadian Treaty (Existing Conditions)</u>. This alternative includes storage nodes for ten U.S. reservoirs and four Canadian reservoirs plus eight non-storage nodes shown in Figure 3. Penalty functions represent all present system goals and priorities, including hydropower, at all U.S. storage projects. Brownlee, an Idaho Power reservoir, has only hydropower penalties.

The operation constraints and penalty functions model operation of the Canadian reservoirs according to provisions of the Columbia River Treaty. In this treaty, the U.S. and Canada agreed that Canada would construct Mica, Arrow, and Duncan dams. These would "... provide 15,500 kaf of storage for power, and 8,450 kaf of primary storage, together with 12,000 kaf of secondary storage for flood control (USACE, 1984)."

<u>Alternative 2: Operation without Hydropower Objectives</u>. This alternative is identical to Alternative 1 except that hydropower penalties are eliminated and replaced with very minor non-economic penalties which encourage releases within the physical limits of the projects.

<u>Alternative 3: Operation with Additional Canadian Treaty Storage</u>. This alternative includes all system components. Penalty functions and operation constraints for all U.S. projects are the same as with Alternative 1 and an additional five million acre-feet of storage is made available at Mica reservoir in Canada.

COMPARISON OF ALTERNATIVE RESULTS

<u>General</u>. Results of the HEC-PRM analysis include prescribed operation for each of the three alternatives. Post-processed results include monthly tabulation of time-series data for each purpose penalty (hydropower, flood control, fish protection, navigation, irrigation, and recreation) and for system flows and reservoir storages. Result comparisons were made for Grand Coulee, system above Grand Coulee, Dworsak, and the system upstream of the Dalles nodes (inclusive). Data for other locations are available but are not included herein in the spirit of brevity. Discussion is limited primarily to the system upstream of the Dalles.

<u>System Operation</u>. The system upstream of The Dalles contains all projects modeled for the HEC-PRM alternatives and HYSSR. The discussion focuses on the April through July refill period. Figure 4 compares monthly flow exceedance at The Dalles during the April - July fish migration season for the three alternatives and HYSSR results. Typically, at The Dalles, Alternative 1 flows have somewhat less seasonal variation than the HYSSR simulation. Alternative 1 late-summer and early-fall releases tend to be greater than for HYSSR. High flows in spring and early summer, common to both HYSSR and Alternative 1, tend to be more consistent for Alternative 1 HEC-PRM operations, with HEC-PRM operation typically having lower peak flows during these periods.

Elsewhere in the system, Alternative 1 tends to keep Grand Coulee full more often in the April through July period than HYSSR results as shown by Figure 5, drawing down Mica earlier in the season for this purpose. Operation of Dworshak reservoir (not shown) is usually similar for HYSSR and Alternative 1, with some tendency to draft earlier in the season.

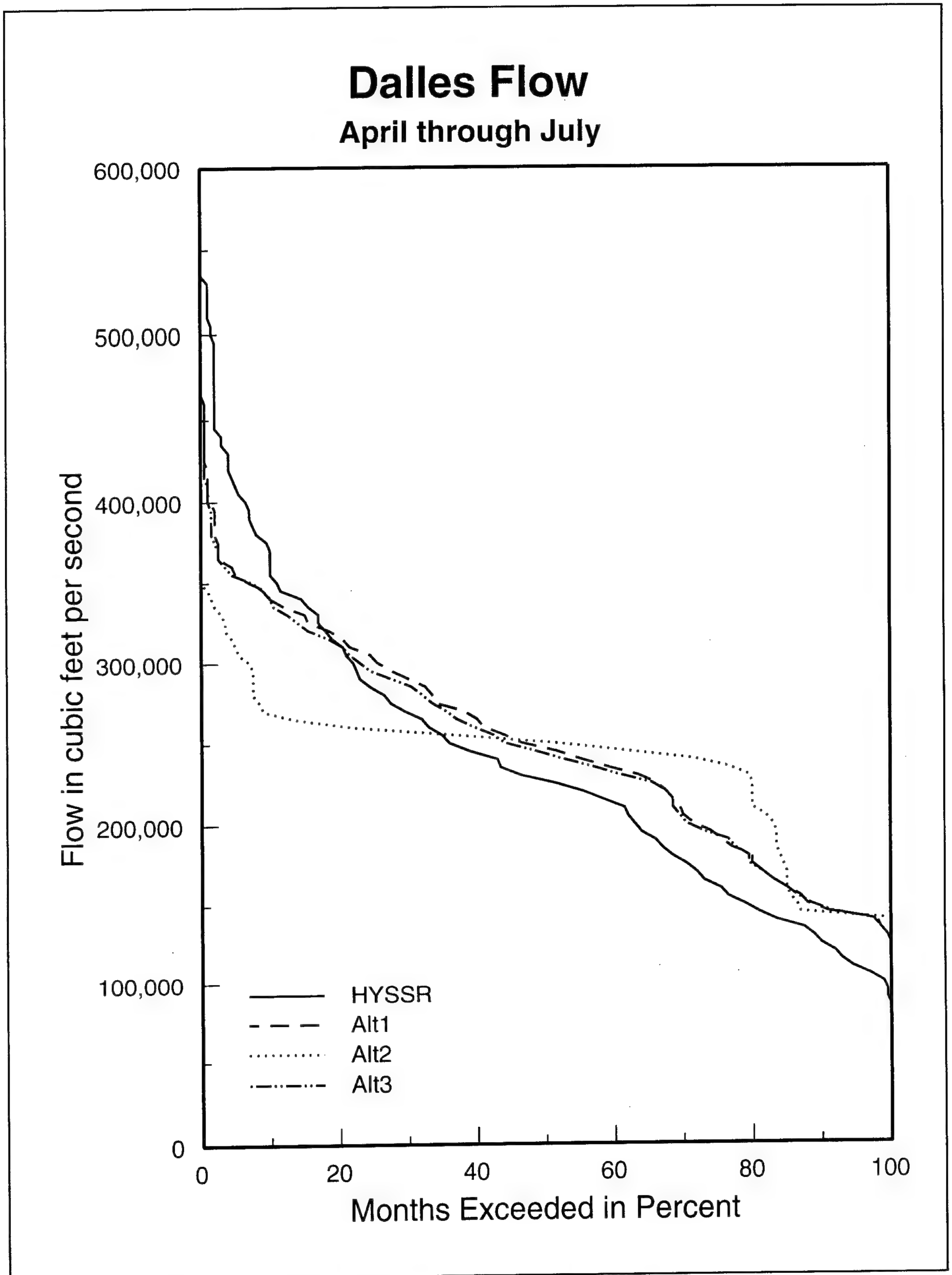

Figure 4. Months Exceeded for The Dalles Flows (April - July)

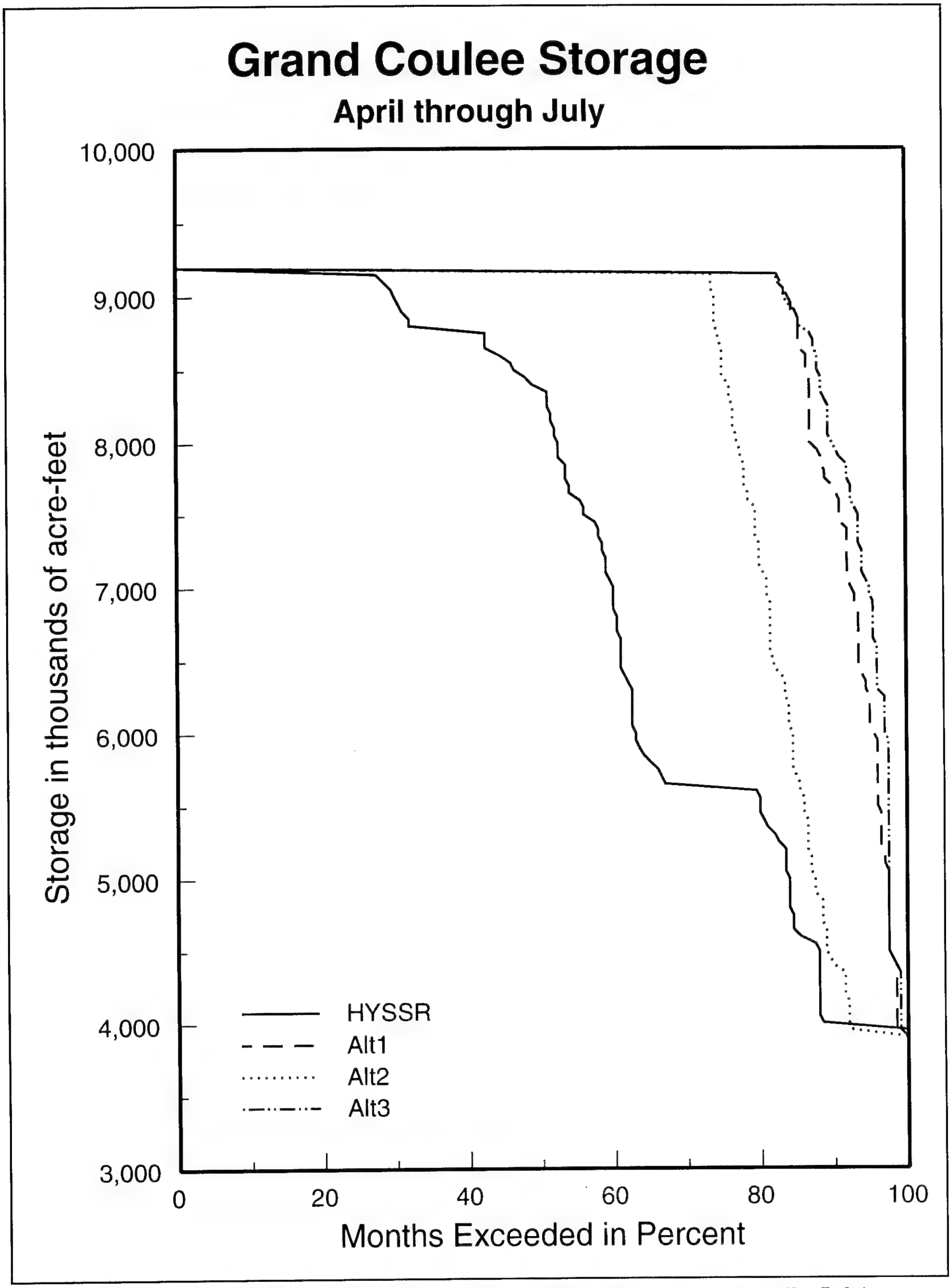

Figure 5. Percent Time Exceedance for Grand Coulee Storage (April - July)

Comparing operations under Alternative 2 (no hydropower penalties) to Alternative 1 operations, flows at The Dalles (Figure 4) tend to have greater seasonal variation with lower flows in fall and greater flows during spring and summer. Flows at The Dalles tend to be somewhat similar during normal years for both Alternatives 1 and 2. Elsewhere in the system, Grand Coulee tends to be drawn down more under Alternative 2 than under Alternative 1, particularly during dry years.

Alternative 3 (additional Canadian Treaty storage) operates essentially as Alternative 1 with the exception of a greater tendency to keep Grand Coulee full at the expense of storage in Mica. Operation of reservoirs on the sub-system above Granite is essentially the same for Alternatives 1 and 3. Flows at The Dalles vary insignificantly between these two alternatives.

System Performance. A series of system-wide indices were computed to assist in comparisons. The indices are presented in Table 1. Table 2 summarizes performance for the alternatives. Alternative 1 compared to HYSSR operation shows reduced penalties for hydropower and all other purposes. Evidently, operation to achieve the minimum hydropower penalty reflected in HEC-PRM, which dominates HEC-PRM system operation, provides net improvement in operation for the other purposes. Relative improvements, while potentially significant for most purposes, are most dramatic for irrigation and recreation purposes. The reliability, resiliency, and vulnerability indices also indicate improvements in operation for all purposes.

Table 1
System-wide Performance Indices Definition

Penalty. Penalty is computed from the individual purpose flow or storage economic penalty functions. The total is the sum of the purpose penalties. The total penalties can be interpreted as economic costs of operation and used to compare alternatives.

Reliability[1]**.** Frequency of meeting the monthly target. Reliability of 100% implies that the monthly target is always met. Targets are defined as follows:

- Flood control: maximum flow with zero damage;
- Fish protection: minimum flow indicated by lowest point on the penalty function;
- Navigation: storage range indicated by the lowest point on the penalty function;
- Irrigation: at least 80% of requirement;
- Recreation: flow or storage range indicated by lowest point on penalty function.

Resiliency[1]**.** This is the frequency of recovering from failing to meet the target in the previous month. Resiliency of 100% implies that the system always recovers.

Vulnerability[1]**.** Average monthly deviation from the target when a deviation occurs. Deviation is defined here as follows: for flood control, difference between actual flow/storage and target; for fish protection, difference between actual flow/storage and target; for navigation, difference between actual flow/storage and minimum if less than target or maximum if greater; for water supply, difference between actual flow/storage and target; for recreation, difference between actual flow/storage and minimum (if prescribed value is less than target) or maximum (if prescribed value is greater than target); for hydropower, difference between actual production and demand (computed for the entire system only).

[1](Hashimoto, et al, 1982)

Table 2
Comparison of Performance: System Upstream of The Dalles (inclusive)

Performance index (1)	HYSSR operation (2)	Alternative 1 (3)	Alternative 2 (4)	Alternative 3 (5)
Penalty, in $ millions for (50-year period)				
Total	133,720.0	122,277.0	130,146.7	121,855.0
Hydropower	128,450.0	118,536.7	127,440.6[1]	118,156.0
Flood control	3,474.0	2,670.5	2,058.3	2,634.2
Fish protection	1,043.9	875.4	499.5	884.0
Navigation	100.0	76.0	11.5	75.7
Irrigation	507.8	66.0	92.1	55.1
Recreation	140.0	48.1	40.5	46.3
Reliability, in %				
Hydropower	62.0	79.5	70.2	81.8
Flood control	79.8	81.5	82.5	81.1
Fish protection	77.9	80.2	83.0	79.9
Navigation	90.8	90.8	97.9	90.8
Irrigation	87.0	89.2	89.1	89.4
Recreation	23.1	44.7	54.9	44.9
Resiliency, in %				
Hydropower	28.9	35.7	40.7	42.2
Flood control	22.7	22.5	24.4	21.4
Fish protection	45.3	49.0	59.3	49.4
Navigation	38.0	44.6	80.0	44.1
Irrigation	30.0	33.4	44.5	35.7
Recreation	5.6	19.0	22.9	18.7
Vulnerability				
Hydropower	761.8	1,098.1	1,628.0	1,130.5
Flood control	2,022.2	2,096.4	2,436.0	2,041.1
Fish protection	3,301.0	2,960.9	2,478.7	2,951.1
Navigation	498.2	427.1	289.8	430.4
Irrigation	2,152.8	1,567.5	1,753.7	1,499.5
Recreation	1,177.2	1,147.5	1,608.5	1,120.6

[1]Hydropower penalty computed via post-processing based on HEC-PRM results without hydropower objective and hydropower penalty functions.

Alternative 2 (operation without hydropower penalties) increases total penalties (with hydropower penalties determined by post-processing system operation results) by \$7,870 million over the 50-year run compared with Alternative 1, averaging about \$157.4 million per year of additional penalty. Comparing results from Alternatives 1 and 2 for the 50-year period, hydropower penalties are \$8,904 million greater for Alternative 2, a 7.5% increase from Alternative 1 hydropower penalties. However, the sum of other penalties is \$1,034 million less. Most of this improvement in non-hydropower penalties is from flood control (\$612 million or a 23% reduction), but substantial penalty reductions also occur for fish protection (\$376 million or a 43% reduction), navigation (\$64 million or an 85% reduction), and recreation (\$7.4 million or a 15% reduction). Irrigation penalties, paradoxically, increased when hydropower penalties were removed, increasing \$26 million or 40% from Alternative 1 results. This is likely due to lessened storage, and therefore greater pumping heads for pumped irrigation withdrawals from Grand Coulee under Alternative 2. (Irrigation penalties are incurred only at Grand Coulee, Granite, McNary, and John Day storage nodes.)

Penalties and performance indices for Alternatives 1 and 3 (with additional Canadian Treaty storage) are essentially the same. The addition of 5 million ac. ft. of storage in Mica decreases total penalty by only \$422 million over the 50-year run period or \$8.44 million/year on average. This implies an average value for storage at Mica of about \$1.68/year per acre-ft of addition storage capacity. There is likely to be considerable uncertainty in this small figure given the uncertainty in existing penalty functions and the absence of economic penalty functions for Mica and Arrow reservoirs.

Results shown in Table 3 indicate that HYSSR and the three alternative operation plans for a period-of-record analysis (1928 - 1978) would generate 22 - 27 percent more average annual energy than the specified average annual energy load. Each would also just meet the average annual energy load during the critical period (1928 - 1932). Despite this, on a monthly basis, all alternatives fail to meet monthly power demands during the critical period. Each of the three alternatives shown in Table 2 have somewhat greater hydropower reliability and resiliency, and lesser penalties, compared with HYSSR results, but may be significantly more "vulnerable," having greater average deviations from hydropower targets.

Alternative 1 hydropower results are significantly more reliable, somewhat more resilient, and significantly less vulnerable than those of Alternative 2. Comparing HYSSR hydropower production to that from Alternative 2, clearly shows that HEC-PRM Alternative 2 (without the hydropower objective) during the critical period (1928 - 1932) yields significantly greater fluctuations in hydropower generation than either HYSSR operations or HEC-PRM operation for Alternatives 1 and 3. While, Alternative 2 average annual production may exceed average annual power demand, the monthly distribution of this generation is less reliable. This is the result of considerable incidental hydropower production from the Alternative 2 operation. Despite being devoid of hydropower penalties, for the analysis period, HEC-PRM operation for Alternative 2 yields 99.88% of the average annual hydropower production of Alternative 1 and 7.5% greater hydropower penalty. During the critical period (1928 - 1932) Alternative 2 hydropower production is 99.31% of the average annual hydropower production of Alternative 1, with comparable hydropower reliability.

Table 3 **Comparison of Average Annual Hydropower Generation:** **System Upstream of The Dalles Node (inclusive)[1] (Megawatt-energy x 10^5)**					
Performance Period	System Load (Demand)	HYSSR Operation	Alternative 1	Alternative 2	Alternative 3
Critical period (1928 - 1932)	1.41	1.42	1.45	1.44	1.46
% Months failing to meet system load		86%	64%	62%	57%
Adopted analysis period (1928 - 1978)	1.40	1.71	1.78	1.76	1.79
% Months failing to meet system load		38%	20%	30%	18%

[1]Table developed from computed monthly average energy values from HYSSR and HEC-PRM results for the period-of-record (1928 - 1978).

SUMMARY

Each of the three alternatives as reflected by HEC-PRM operations provides apparent improvement over present system operation as reflected by HYSSR operation based on performance criteria previously described. This is mostly spurious because of the difference in reflecting seasonal hydropower demands. The average annual energy is essentially the same as present operation for all alternatives. This indicates a small amount of spillage throughout the system. The average annual energy produced exceeds the demand for the 50-year period and just meets the demand for the critical period (1928 - 1932). Additional analyses are required to determine how the alternatives meet the demand on a seasonal or monthly basis.

Alternative 3, the use of an additional 5 million acre-feet of Mica storage, causes an expected, significantly different operation at Mica than Alternative 1 which optimizes for present conditions. This results in more stable operation of Grand Coulee pool levels (from visual inspection of the time-series plots) but little effect downstream at The Dalles or in other sub-systems (e.g., above Granite).

Alternative 2, which omits the hydropower objective, clearly shows enhanced reliability and resiliency for system navigation, recreation, and fish protection (see Table 2). It is also significantly less vulnerable for fish protection and navigation, although it is significantly more vulnerable for hydropower, flood control and recreation. Additional study of seasonal effects of this alternative on the fishery and more detailed assessments of the impact on seasonal, monthly

and daily hydropower requirements seem warranted. The major operational differences for Alternative 2 operations, compared with Alternative 1, are greater seasonal variation in system outflows during dry years, and less Grand Coulee storage.

Conclusions. HEC-PRM can provide useful information for comparisons of system operation alternatives for the Columbia system.

The utility of the results reported herein is lessened due to shortcomings in this particular HEC-PRM model of the Columbia River System. These shortcomings include the absence of seasonally varying hydropower penalties and the absence of a complete set of penalty functions for some reservoirs in the system, notably at Mica, Arrow, and Brownlee.

HEC-PRM results for this system appear to be reasonable and offer economically-supported insight into improved system operation under a wide variety of conditions. Such results are useful for performance and comparison of operation alternatives at the planning stage. This is the use here, where current operational objectives and conditions are compared with those given additional Canadian Treaty storage (Alternative 3) and with elimination of hydropower as an operating objective (Alternative 2).

Epilogue. Another use of HEC-PRM results, for promising operation alternatives, is as a basis for developing operation rules. This approach has been taken for the Missouri River system (USACE, 1992a and 1992b) and following the study for the Columbia River system (USACE, 1993) reported herein, was undertaken for the Columbia results. Results show that analysis of HEC-PRM can provide detailed and specific suggestions for improvement of system operating strategies and operating rules. Additionally, there is potential for the use of HEC-PRM for shorter periods, ranging from seasonal or annual operation to operation planning over a few years time horizon (USACE, 1994). The California Department of Water Resources uses a somewhat similar approach with great success for its near-term operational planning (Chung, et al., 1989).

ACKNOWLEDGMENTS

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BILL WILLIAMS RIVER WATER MANAGEMENT CONFLICT RESOLUTION STRATEGY

by

Joseph B. Evelyn[1]

INTRODUCTION

<u>Overview</u>. This paper describes how seven agencies with different responsibilities, goals, and priorities worked together to reach a consensus on the best operation plan for a multi-purpose Corps of Engineers reservoir project, Alamo Dam. Although the technical aspects of the issues and solution are interesting, the resolution process followed to reach a consensus may be the most useful information for others wrestling with decision-making involving competing interests for a limited natural resource. The resolution strategy involved the development of a true partnership with the other agencies in which each participant came to understand and respect the importance of the other agencies' needs and objectives. A relatively lengthy education process for the group led to a clear understanding of the project's operational constraints, hydrologic aspects of the watershed, and institutional priorities. A key activity was the definition of optimum river flow and lake level regimes for each natural resource objective, independent of the other objectives. Having established this informational foundation enabled a straightforward evaluation and comparison of alternative operation plans once the performance results of each operation were generated by hydrologic modeling. The recommended operation plan for Alamo Dam benefited both natural resource objectives and congressionally authorized project purposes, producing a "win-win" outcome.

<u>Problems and Needs</u>. In the mid- to late 1980's, the Arizona Game and Fish Department (AFGD), Arizona State Parks (ASP), Bureau of Land Management (BLM), and U.S. Fish and Wildlife Service (USFWS) were working independently to influence the operation of Alamo Dam (Bill Williams River Corridor Technical Committee, 1994), and/or secure water rights to achieve their respective agency goals along the Bill Williams River (Figure 1). The Corps of Engineers faced frequently conflicting requests for operational changes at Alamo Dam to meet various objectives that were in the public interest. Agency and public concerns included the maintenance of Alamo Lake elevations for recreational use (especially fishing), the pattern of dam releases degrading downstream riparian and aquatic ecosystems, and the maintenance of an adequate lake surface area for foraging by two nesting pairs of endangered bald eagles. In addition, the congressionally authorized project purposes of flood control, water conservation, and recreation, as well as project maintenance requirements also had to be considered in any operational decision-making.

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Figure 1- General Location Map

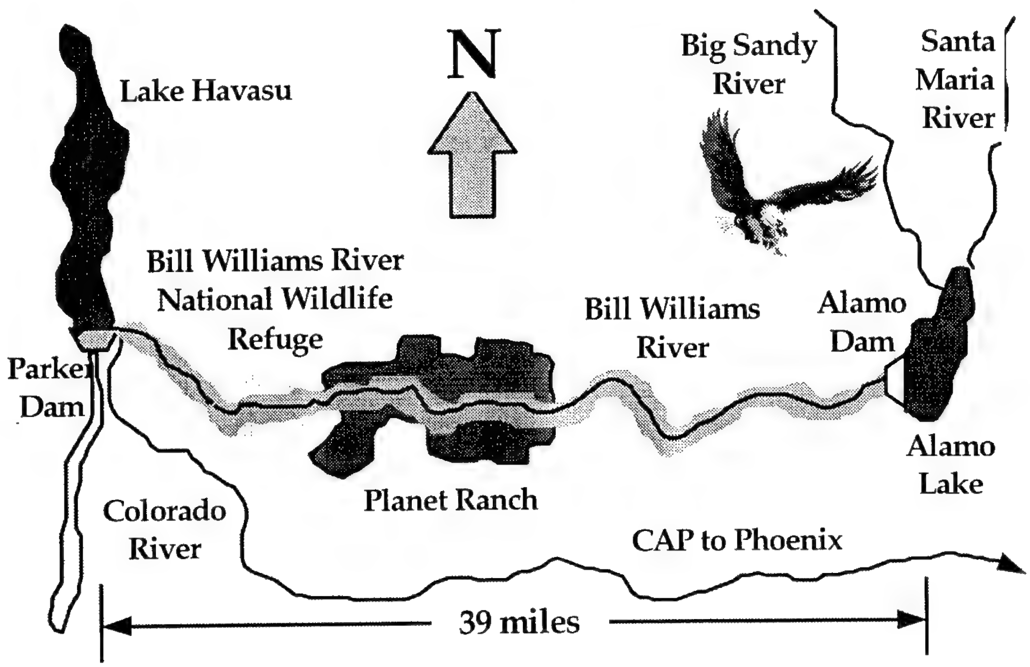
Early Study Efforts

1) The Corps completed a Section 216 Reconnaissance Study (Corps of Engineers, 1990) that evaluated alternative reservoir operation plans formulated to benefit a single objective at a time: (1) water conservation, (2) recreation, and (3) bald eagle enhancement. The study concluded that diversion of Bill Williams River water to the Central Arizona Project was not economically feasible, and that the Corps could exercise existing authority to reallocate storage and re-regulate the reservoir for the aforementioned purposes. The Corps recommended that all issues, problems, and opportunities identified in the Reconnaissance Study be evaluated in a Federally-funded Water Control Study with the goal of establishing the optimum storage allocation and operation schedule for all Alamo Lake purposes. As the local sponsor for the reconnaissance study and the State's water management agency, Arizona Department of Water Resources (ADWR) requested that a coordinated effort be initiated among the affected agencies to resolve conflicts and seek common ground in the management and operation of water resources along the Bill Williams River.

2) In the spring of 1990, AGFD initiated dialogue among ASP, BLM, and USFWS regarding development of a coordinated, interagency planning effort focused on the management of water resources in Alamo Lake and the Bill Williams River. The agencies recognized that working cooperatively offered the best chance to achieve a comprehensive water management agreement that would optimize all agency management goals. In August 1990 a coordination meeting of upper level management from these four agencies and the Corps was held to establish an interagency planning team with instructions to develop a comprehensive water resource

management plan for the Bill Williams River corridor. The study area was established as the Bill Williams River from the confluence of the Santa Maria and Big Sandy Rivers at the upper end of Alamo Lake, to the confluence of the Bill Williams River and Colorado River at Lake Havasu (Figure 2). It was recognized that water management along the Bill Williams River corridor, in terms of lake elevation and streamflow regime, was the key to achieving all agency goals. Two interagency committees were established (Steering and Technical) to develop a corridor modeling approach to address the issues.

Figure 2- Bill Williams River Corridor Location Map



Technical Committee. The interagency planning team conceived by the five agencies became the Bill Williams River Corridor Technical Committee (BWRCTC). The goal of the Technical Committee was to carry out a coordinated interagency planning effort to develop an effective water management plan for Bill Williams River corridor resources. Alamo Dam operation affected threatened and endangered species, warmwater sportfisheries, water-based recreation, riparian habitat, and wildlife. As the dam controlled lake elevation and downstream flow regime, the Technical Committee focused its efforts on Alamo Dam operation, which was also the one factor over which public agencies already had institutional control. The Technical Committee was guided by a Steering Committee-approved 13-step process summarized below:

- Assemble a technical committee of representatives from each agency.
- Identify each agency's resource goals and objectives.
- Each agency acknowledges the importance of other agency objectives.
- Determine individual water management regimes that optimize values and benefits for riparian, fisheries, wildlife, and recreation resources independent of each other.
- Develop alternative reservoir operation plans that best meet collective resource goals.
- Analyze and evaluate those alternative reservoir operation plans.
- Select the reservoir operation plan that best meets all agency resource objectives.
- Submit the recommended operation plan for approval and implementation by the agencies.

After the first year the Technical Committee was expanded to include the Bureau of Reclamation (USBR) and ADWR, although ADWR participation was in an advisory role rather than as an advocate of Technical Committee determinations. The USBR operates the reservoir system on the Colorado River into which the Bill Williams River flows. The agencies participating on the Bill Williams River Corridor Technical Committee were:

- Arizona Game and Fish Department
- Arizona State Parks Department
- Arizona Department of Water Resources
- U.S. Bureau of Land Management
- U.S. Bureau of Reclamation
- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service

Description of Study Area. Alamo Dam is located on the Bill Williams River, 39 miles upstream from its confluence with the Colorado River at Lake Havasu (Figure 2). The dam controls 4,770 square miles of drainage area comprising broad desert valleys and irregularly distributed ranges of rugged mountains. Elevations range from 990 feet above mean sea level at the dam to 8,226 feet at Hualpai Peak on the northwest boundary. Except for small areas at the higher elevations, the density of vegetation is low. The high elevations support pines in open woodland along with various grasses. Below the pines is a pinon-juniper belt extending down to about elevation 5,000 feet; charparrel and short grasses occupy the next lower band down to about 3,500 feet. Below 3,500 feet the vegetation is typically desert, consisting of such plants as creosote bush, salt bushes, cat's claw, and cactus. Mean annual precipitation ranges from about 9 inches at the dam to 22 inches along the crest of the mountains near Prescott. Normally, about one-third of the annual precipitation occurs during July and August, and about one-half in the fall and winter months. Due to the hydrologic characteristics of the watershed (steep gradients, impervious soil formations, and fan-shaped runoff patterns), runoff tends to be characterized by high peaks discharges of relatively short duration.

1) The Alamo Lake recreation area includes 22,856 acres of Corps-withdrawn lands. Fish and wildlife management responsibilities for the entire area have been turned over to the AGFD under a license agreement. Of the total 22,856 acres, 17,963 acres are specifically managed as the Alamo Wildlife Area by the AFGD, while recreation management of the

remaining 4,893 acres is the responsibility of ASP under a separate lease agreement with the Corps.

2) Alamo Lake supports a productive warmwater fishery characterized by the popular largemouth bass. A quality fishery, coupled with other water-based recreational opportunities, supports substantial recreation use at the lake. Recreation facilities provided at Alamo Lake are operated by ASP and include a 160-acre day use area, trailer campsites with hookups, campsites, picnic areas with ramadas, swimming area, three boat launching facilities, and associated parking areas.

3) The Bill Williams River riparian corridor contains the last extensive native woodland riparian habitat along the lower Colorado River. Riparian vegetation and the open surface water of the Bill Williams River are the principle components of this unique desert habitat, supporting an abundance and diversity of wildlife, including fish. Flows in the river have been regulated by Alamo Dam since its completion in 1968. River flows in the lower 15 miles are also affected by water uses for agriculture at Planet Ranch (see Figure 2).

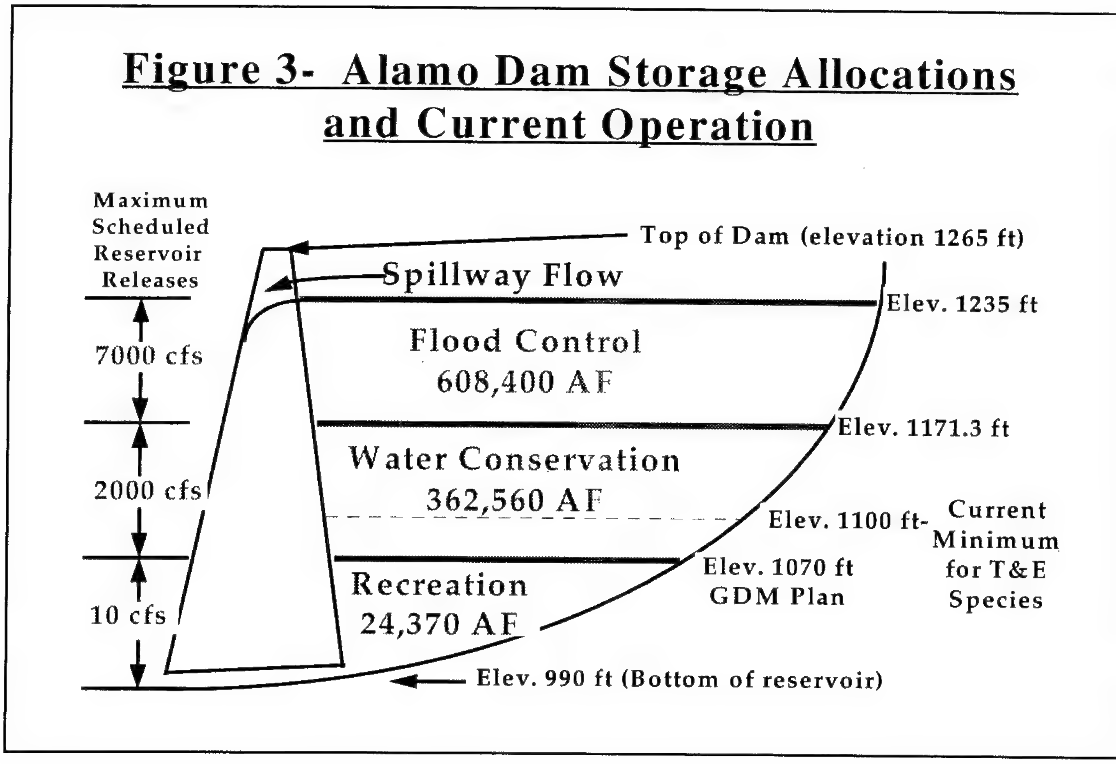
4) There are two BLM Wilderness Areas along the Bill Williams River, the Rawhide (2,700 acres) immediately below Alamo Dam and the Swansea (1,900 acres) immediately above Planet Ranch. The majority of landownership along the Bill Williams River is federal (BLM and USFWS), however a small number of private parcels occur along the 39 mile reach. The Bill Williams River National Wildlife Refuge was established in 1941 and covers 6,105 acres along the lower 9 miles of the river. The Refuge was established following Parker Dam construction as mitigation for loss of riparian habitat along the mainstem lower Colorado River, and as a breeding ground and refuge for migratory birds and other resident wildlife.

ALAMO DAM AND RESERVOIR

Alamo Dam. Alamo Dam was constructed as a multipurpose project under authorization of the Flood Control Act of December 22, 1944 (Public Law 534, 78th Congress, 2nd Session). A General Design Memorandum report (Corps of Engineers, 1964) was prepared to document the design of the project. Construction of the zoned earthfill structure began in July 1963 and was completed in July 1968. The dam is 283 feet high (top of dam is 1265 feet) with a crest length of 975 feet. Gross storage at spillway crest (elevation 1235 feet) was 1,043,000 acre-feet when first completed. The spillway is a detached broadcrested weir consisting of a unlined trapezoidal section cut through a rock saddle located in the right abutment. Reservoir releases of up to 7,000 cubic feet per second (cfs) are made through 3 pairs of slide gates located in the left abutment.

Project Purposes. Allocations of reservoir storage space were authorized for flood control, water conservation, and recreation as depicted in Figure 3. Alamo Dam is operated in accordance with the Reservoir Regulation Manual for Alamo Lake (Corps of Engineers, 1973).

1) Flood Control. Alamo Dam was authorized to provide flood control along the lower Colorado River downstream from Parker Dam (Lake Havasu), and along the Bill Williams River. Flood control is achieved by limiting reservoir outflow to a maximum of 7,000 cfs.



2) Water Conservation. Runoff captured in the water conservation pool is released at rates up to 2,000 cfs in coordination with the USBR operation of the Colorado River reservoir system. Several important factors with regard to flexibility of water conservation operation provide an opportunity for addressing other needs and concerns. First, none of the water conservation storage space has been contracted for. Second, due to its remote location, Bill Williams River water has not been fully appropriated by the State of Arizona. And third, Bill Williams River water is legally State of Arizona water until it reaches the Colorado River, at which point it is administered in accordance with the body of laws, agreements, and regulations governing Colorado River water use.

3) Recreation. A recreation lake with a minimum surface area of 500 acres is to be maintained. Releases from the recreation pool are limited to about 10 cfs to meet downstream water rights along the Bill Williams River. As a result of a 1987 USFWS letter to the Corps, the pool elevation is not lowered below 1100 feet, to provide sufficient forage area for the endangered bald eagles which nest in the vicinity of the lake.

Current Issues and Concerns.

1) Due to a series of above normal runoff years (1983-86) during which the lake was operated at or above elevation 1110 feet, in combination with the subsequent 1100 feet minimum lake elevation requested by USFWS, ASP constructed boat launch ramps and other recreation facilities designed for usage at water surface elevations above 1100 feet. The new facilities, coupled with the higher lake elevation, increased annual recreational usage because of the larger lake surface area.

2) The AGFD has established a successful and highly popular largemouth bass fishery at Alamo Lake. Largemouth bass spawning success can be negatively impacted by fluctuating lake levels during the spawning season.

3) In the early 1980's a pair of Southern Bald Eagles, a Federally listed endangered species, was discovered nesting in a partially inundated tree within the upper reaches of Alamo Lake. Subsequently, another pair was discovered nesting on a bluff in the canyon wall downstream of the dam. The use of the lake by the eagles for foraging prompted the USFWS to request that the lake elevation remain within the range of 1100-1135 feet for the preservation of the eagles. The request was in accordance with the National Environmental Policy Act and the Endangered Species Act. The 1135 foot maximum lake elevation was requested to prevent inundation of the reservoir nest.

4) The construction of Alamo Dam has dramatically altered the downstream Bill Williams River flow regime in terms of flow magnitude, duration, frequency, and timing. Although the watershed has produced flood events with peak discharges in excess of 60,000 cfs at least 14 times in the last 104 years, the dam has limited outflows to a maximum of 7,000 cfs since its completion in 1968. Unregulated flood events have a beneficial effect on germination and recruitment of new riparian vegetation, and rapidly recharge the alluvial groundwater aquifer. By 1978, 10 years after dam completion, an estimated 70 percent reduction in riparian areas had occurred as compared with historic levels (Ohmart 1978). Riparian communities were adversely affected by the lack of adequate base flows, sustained inundation of their root zones during lengthy water conservation releases of moderate magnitude (1000-2000 cfs), and alteration of the natural seasonal pattern of flows. Because of the dam's adverse impact on riparian vegetation, various resource agencies sought modification of the release patterns from Alamo Dam to help restore and maintain the riparian areas. Recommended releases have included requests for higher peak discharges (up to the 7,000 cfs), mimicking of natural pre-dam spring and summer (monsoon) flood events, avoidance of sustained inundation which causes mortality of mature trees, and providing adequate base flows that sustain downstream riparian habitat through long hot Arizona summers.

5) Corps regulations require a complete inspection and engineering evaluation of the dam every five years. Inspection of the outlet tunnel upstream of the service and emergency gates requires installation of a bulkhead gate over the outlet tunnel intake structure. The original bulkhead gate installation system was designed to function with a lake level at elevation 1070 feet (the authorized recreation pool elevation). The current system has been modified (strengthened bulkhead gate and a winch system) to work for pool levels up to elevation 1110 feet, the maximum elevation that the intake structure can handle the hydrostatic loading from the gate. Because of the potential for sudden flood inflows, the pool has been drawn down to elevation 1100 feet for inspection and maintenance, providing a buffer of about 10 feet, to enable sufficient time for bulkhead removal before the pool can rise to elevation 1110 feet or higher. In summary, at five year intervals the prescribed inspection and/or maintenance requires a pool level below elevation 1110 feet. For high flow years with large reservoir storage, it may require a reservoir drawdown that conflicts with achieving certain reservoir operation goals and objectives.

IDENTIFIED RESOURCE GOALS

As part of the original Technical Committee 13-step process, goal statements were requested from each agency. There was a significant degree of commonality among agency goals and concerns. Following is a consolidated list of resource goals identified by each agency.

- Restore, maintain, and enhance Bill Williams River Corridor ecosystem with emphasis on riparian and wetland habitats.
- Enhance fish and wildlife habitat, including habitat for endangered and threatened species.
- Provide habitat for migratory birds.
- Preserve the wilderness character of designated wilderness areas.
- Provide for high quality wildlife-oriented recreational opportunities.
- Enhance recreational opportunities at Alamo Lake.
- Maintain and enhance the quality of recreational and warmwater fishery at Alamo Lake.

FORMULATION OF ALTERNATIVE RESERVOIR OPERATION PLANS

Technical Subcommittees. The next step in the process was to determine the optimum lake elevation and/or Bill Williams River flow regime to achieve the resource agency goals and objectives identified by the Technical Committee. In order to best carry out this activity the Technical Committee decided to form five subcommittees covering the following five categories: riparian, fisheries, wildlife (including threatened and endangered species), recreation, and reservoir operations (including flood control, water conservation, and project operation and maintenance requirements). Each Technical Subcommittee developed lake elevation and river flow recommendations that optimized benefits for their respective resource goals independent of the other subcommittees. This was an extremely important activity. The Technical Subcommittees were comprised of Technical Committee members and other agency resource experts in each field. Outside experts were invited to share their specialized knowledge in certain areas. It was sobering to learn that significant differences existed among experts on what constituted optimum lake or flow conditions for a given objective, what deviation from that optimum was acceptable (for how long, what time of year, how many years in a row, etc.), and what conditions were considered adverse (where recovery would be difficult or unattainable). For example, for each month of the year how long can the root zone of cottonwood trees be inundated with beneficial effects, some short term acceptable impact, and adverse long-term impact that could result in mortality? Or what is the minimum lake surface area necessary to provide adequate forage area for the bald eagles nesting in the vicinity of the lake? These types of questions and issues are not amenable to exact or precise determination. The judgment of subject matter experts working together to arrive at a consensus best estimate was the work of each subcommittee. At the conclusion of an intensive effort by each subcommittee, a written report was prepared by each subcommittee that detailed its recommendations for optimum Alamo Lake elevation(s) and optimum downstream flow regime by month (Bill Williams River Corridor Technical Committee, 1994). These subcommittee reports provided a sound basis for the formulation of alternative reservoir operation plans, and quantitatively comparing the performance of alternative plans based on subsequent period-of- record simulation modeling of Alamo Lake and downstream flow conditions.

Formulation of Alternatives. The formulation of alternative plans was based on meeting and enhancing various natural resource objectives, while considering project authorized purposes and project inspection/maintenance requirements. The five subcommittee reports were analyzed to identify both common ground and areas of conflict. Operational recommendations for the fisheries, recreation, riparian, and wildlife resource categories were subject to project authorities, physical limitations of the dam, and project inspection/maintenance constraints detailed in the Alamo Reservoir Operations Subcommittee report. Streamflow requirements for riparian habitat, as recommended by the Riparian Subcommittee, were the key to establishing the reservoir release pattern for alternative operation plans. For the Bill Williams River corridor, wildlife resources as well as riparian habitat would be optimized by meeting streamflow requirements recommended by the Riparian Subcommittee. Fisheries, Wildlife, and Recreation Subcommittees each recommended that 1100 feet be considered the minimum lake level. Lake levels above 1100 feet are desirable, but must consider risks of inundating potential bald eagle nests (historically at 1124-1138 feet). The Fisheries and Recreation Subcommittees preferred lake elevations managed from 1110-1125 feet and when these elevations were exceeded, both Subcommittees preferred rapid evacuation of flood inflows to minimize periods of lake fluctuation. Other common features among the subcommittee recommendations aided in reaching consensus in developing alternative operational schemes.

Description of Alternatives. The alternative reservoir operation plans were developed around the concept of a "target elevation" that serves as an optimal reservoir pool level to be at anytime of the year. Because of the highly variable volume of annual runoff (see Figure 4), water needs to be held in storage when available, in order to meet resource objectives both at the lake and downstream during a series of dry years. When flood inflows cause the lake to rise above the target elevation, releases are stepped up to maximum of 7,000 cfs to mimic a natural flood event. Between the target elevation and the minimum acceptable lake elevation of 1100 feet, releases of 25-50 cfs (varies by season) are made to fully satisfy the water needs of downstream riparian habitat. As the pool level falls below 1100 feet, releases for riparian habitat are reduced to rates (10-25 cfs) that are the minimum necessary to sustain downstream habitat (see Table 1). This operation shares the burden of a drought condition with both lake and downstream river resource objectives.

1) Each alternative plan was based on a different target lake elevation: 1115, 1120, 1123, 1125, 1127, 1130, 1140, and 1171.3 feet. The alternative plans were compared to the original authorized operations at 1070 feet (General Design Memorandum or GDM) and current operations, which attempt to maintain minimum pool elevations of 1100 feet (per USFWS 1987 request for the bald eagles).

2) A standard release pattern was applied to all the alternatives. When the reservoir pool rises above the target elevation, reservoir releases are increased by 1,000 cfs per foot of reservoir rise until the maximum release of 7,000 cfs is reached, or the outlet capacity is reached. The same stepped operation is followed on the flood recession as the pool level drops toward the target elevation. This operation best mimics the natural flood hydrograph shape for this watershed.

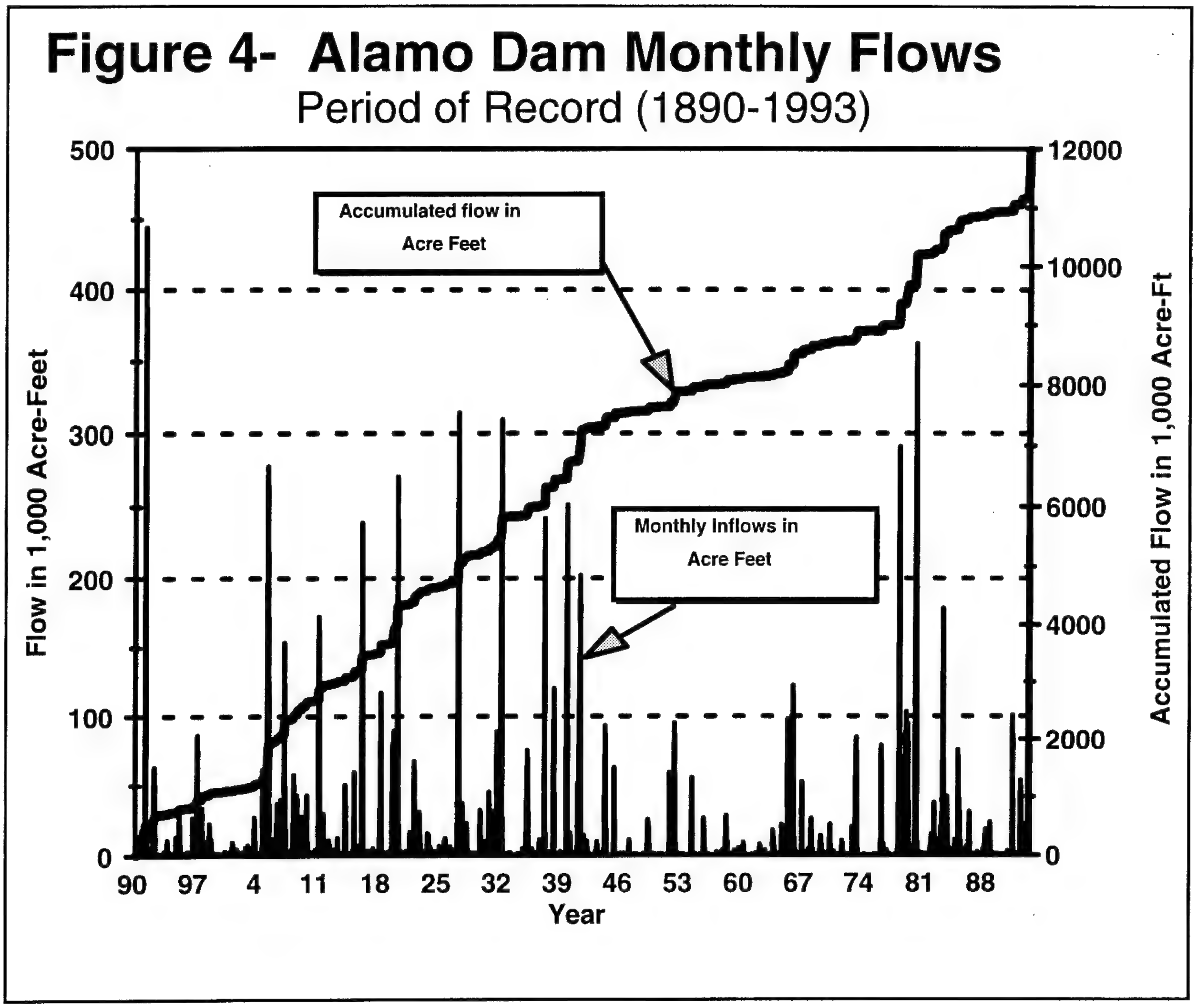


Table 1
Generalized Alamo Dam Release Schedule for Alternative Operation Plans.

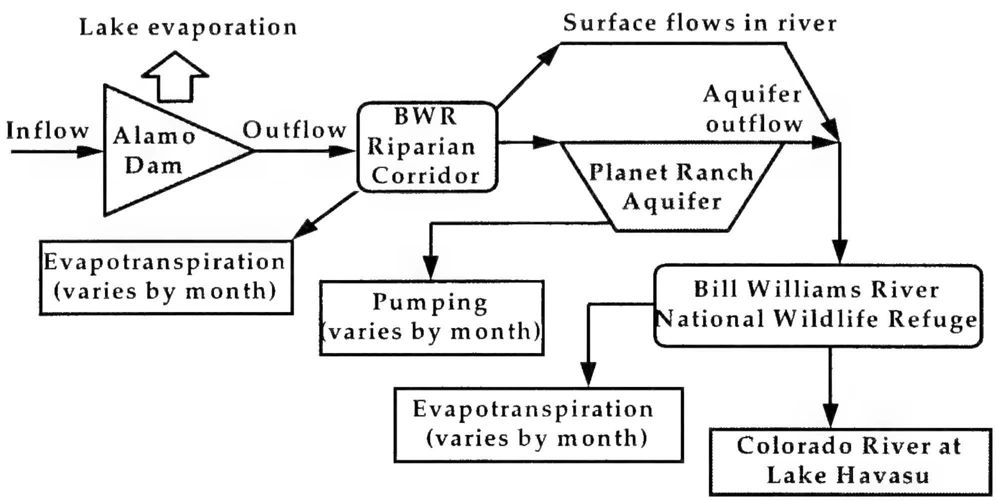
Lake Elevation (feet, msl)	October	Nov- Jan	Feb- Apr	May- Sept
	Alamo Dam Releases (cfs) by Month			
990-1070	10	10	10	10
1070-1100	15	10	25	25
1100 to Target Elevation	40	25	40	50

Note. These releases apply if the current lake elevation is less than or equal the target elevation.

EVALUATION OF ALTERNATIVE RESERVOIR OPERATION PLANS

Evaluation Tools: HEC-5 Model. The Corps of Engineers' HEC-5 "Simulation of Flood Control and Conservation Systems" computer program (Hydrologic Engineering Center, 1982) was the principal hydrologic modeling tool used by the Technical Committee. HEC-5 simulates river and reservoir system operation on a continuous basis using flow data, reservoir characteristics, channel characteristics, and evaporation data as model input. A schematic of the Bill Williams River system as modeled in this study is shown in Figure 5. Note that the Planet Ranch groundwater aquifer was modeled as a reservoir in the system. Using available geologic information, the aquifer storage was estimated to be 366,000 acre-feet. When the aquifer storage was filled, additional infiltration was assumed to flow from the aquifer in a manner similar to free flow from a dam's ungated spillway. The additional infiltration was combined with the surface flows through the Planet Ranch area; this combined flow was routed to the Refuge.

Figure 5- Schematic of BWR Stream and Reservoir System



1) Inflows to Alamo Reservoir were daily average flows in cubic feet per second (cfs) for the period October 1, 1928 through December 31, 1993. This period of record was compiled from three data sources: U.S. Geological Survey (USGS) stream gage data at the Alamo damsite (1939-68), computed flow values from the Corps' daily operation records of Alamo Dam (1968-93), and flows derived from correlating measured flows at the USGS gages at the Alamo and Planet Ranch sites (1929-39). The measured flows were from the period 1940-46 when both gages were simultaneously in operation.

2) Monthly inflows into Alamo Reservoir for the period of record are shown in Figure 4. The high degree of variability of Alamo Reservoir inflows is readily apparent from this figure.

Although monthly flow data could be estimated back to 1890, a daily flow record was necessary to address rate of change of lake level objectives and flood hydrograph shape criteria that were important factors in measuring operation plan performance.

3) Mean monthly evaporation values at Alamo Reservoir were computed from pan evaporation data collected at the damsite. Evapotranspiration losses along the Bill Williams River were obtained from research on the Bill Williams River riparian vegetation (Harshman and Maddock, 1993). Monthly average pumping rates of Planet Ranch groundwater were also obtained from Harshman and Maddock (1993). The pumping was treated as an abstraction from the Bill Williams River system; no irrigation return flow was assumed to enter the aquifer or the Bill Williams River.

4) Each of the alternative Alamo Dam operation plans was simulated for the 65 year period 1928 to 1993, to provide daily values of lake level and flow rates throughout the Bill Williams River corridor. A post-processor program for the HEC-5 runs was developed to extract specific data and compile pertinent statistics used in evaluating the performance of the various alternatives. A useful procedure developed to provide all participants the information from the HEC-5 runs was to compress the HEC-5 output file for each run onto floppy discs that were distributed at each Technical Committee meeting. An unzip utility was also provided that permitted expansion of the compressed files, and viewing of each run using any text editor. This allowed each Technical Committee member to review the runs to verify the model was performing as desired, postulate operational modifications that might benefit resource objectives, and in general increase the confidence level of non-engineers/hydrologists in how HEC-5 was really performing the computations.

Evaluation Criteria. The factors for evaluating the performance of the various alternatives and comparing to the GDM plan and Current Operation were established by quantifying the specific lake level and river flow regime information determined in the technical subcommittee reports. The needs and concerns for the resource demands of Alamo Dam and Reservoir are lake fisheries, wildlife concerns, lake recreational opportunities, riparian habitat, flood control capability, and water conservation potential. Table 2 is an abbreviated list comprising the most important evaluation criteria that the subcommittees decided upon for each resource category.

Evaluation of Alternatives.

1) A total of 14 alternatives were simulated in HEC-5 period-of -record runs, of which two represented baseline scenarios (GDM and Current Operation), eight represented "target" lake elevations ranging from 1115-1171.3, and four were special runs to examine the sensitivity of Planet Ranch groundwater withdrawals, and Alamo Dam drawdown frequency for inspection and maintenance. Table 3 summaries the results of the simulations for four operating plans for the selected evaluation criteria. The complete table of evaluation criteria results for all alternatives requires substantially more space to present. However, the concepts used in the evaluation process are adequately demonstrated using this abbreviated presentation of results. The Technical Committee was now in a position to compare quantitatively the performance of the various alternatives, and select the best overall plan.

Table 2
Selected Evaluation Criteria

- Recreation
  - * RE3- Percent of time Alamo Lake elevation at or above 1108 feet
  - * RE4- Percent of time Alamo Lake elevation between 1115 and 1125 feet
- Water Conservation
  - * WC1- Average annual delivery of water to Colorado River in acre-feet
  - * WC2- Average annual lake evaporation in acre-feet
- Flood Control
  - * FC1- Number of days Alamo Lake is above 1171.3 feet during 1929-1993
  - * FC2- Maximum percent of flood control space used 1929-1993
- Fisheries
  - * F1- Percent of time Alamo Lake elevation is between 1110 and 1125 feet
  - * F2- Percent of time March to May lake fluctuates greater than 2 inches/day
- Wildlife
  - * W1- Percent of time Alamo Lake elevation is at or above 1100 feet
- Riparian
  - * RA3- Percent of time Alamo releases greater than or equal 25 cfs in Nov-Jan
  - * RA4- Percent of time Alamo releases greater than or equal 40 cfs in Feb-Apr, and Oct
  - * RA5- Percent of time Alamo releases greater than or equal 50 cfs in May-Sep

Table 3- Partial Alternative Evaluation Summary

Alternative Operation Plans	Recreation		Water Conservation		Flood Control		Wildlife	Fisheries		Riparian		
	RE3 %	RE4 %	WC1 af	WC2 af	FC1 days	FC2 %	W1 %	F1 %	F2 %	RA3 %	RA4 %	RA5 %
GDM Plan	1.8	0.4	65322	5857	16	13.8	2.1	0.7	13.1	15.2	22.9	9.3
Current Oper	3.2	0.6	58735	13145	27	16.8	36.9	1.2	11.5	13.8	20.9	6.8
A1125D05	49.0	34.6	53174	16106	0	0	69.5	43.6	4.6	59.6	70.3	61.2
A1140D05	56.0	10.2	51267	17842	7	8.8	71.9	15.9	4.4	61.4	74.1	63.9

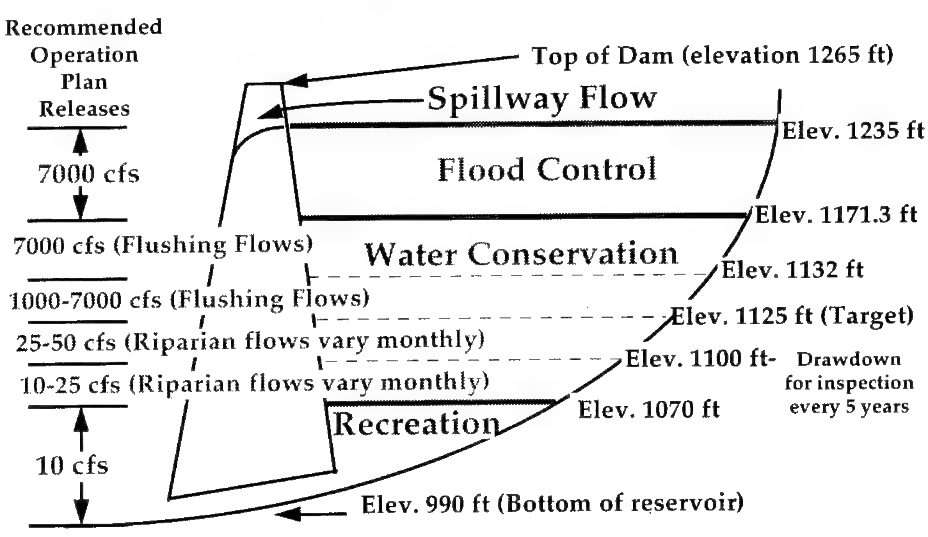
Evaluation criteria (RE3, RE4, WC1, FC1, F2, etc..) are specific measures of the performance of each alternative with respect to resource objectives established in the subcommittee reports.

2) Alternatives storing more water than the current operation (i.e., target elevation higher than 1100 feet) performed much better in terms of meeting evaluation criteria. Flood control performance was significantly improved for all the alternatives evaluated because the initiation of large releases is made much earlier than under GDM or current operation, in which releases are limited to 2,000 cfs from the conservation pool. The above operation plans designated as A1125D05 and A1140D05 are alternative reservoir operation plans with target elevations of 1125 feet and 1140 feet, respectively, and Alamo Reservoir drawdown for inspection and maintenance every 5 years. Note that for shaded columns, smaller values or percentages are better at meeting resource objectives.

RECOMMENDED PLAN

Selection of Recommended Plan. The desired outcome of the Technical Committee was to develop an operation plan for Alamo Dam which balanced the five resource objectives within the limits of the available watershed runoff and Alamo Dam operational constraints. By consensus, the 1125 foot target elevation operation plan was selected as the best alternative in terms of overall performance in meeting the established resource objectives. The 1125 foot plan provides 80,000 acre-feet of lake storage above the 1100 foot minimum desired lake level. This large volume of storage is available to meet riparian, fish, wildlife, and recreational needs. Figure 6 depicts the recommended Alamo Reservoir operation plan. Note that reservoir operation in the authorized flood control and recreation pools remains essentially unchanged from the GDM plan.

Figure 6- Alamo Dam Recommended Operation



Benefits of Recommended Plan. Positive benefits for fish, wildlife, riparian habitat, recreation, and flood control result from altering the releases made from the water conservation pool to vary with season and reservoir elevation. In fact, during the 65 year simulation with the recommended operation plan the reservoir water surface elevation never even reaches the flood control pool. In changing from current operations to the recommended 1125 foot plan, improvements in evaluation criteria occur for all categories, except water conservation (Table 3). Although there is a net reduction in total water delivery to the lower Colorado River, there is an increase in the water provided for in-stream riparian habitat. The consumptive use of water by riparian habitat along the Bill Williams River under the recommended dam operation is closer to the consumptive use of water under pre-Alamo Dam conditions. In addition, the estimate of average annual reduction in water delivered to the Colorado River is actually overstated in this study because the scope of modeling was limited to the Bill Williams River corridor. The estimated water deliveries were not adjusted for reduced evaporation losses occurring in mainstem Colorado River reservoirs that would release additional water to compensate for a reduction in contribution from the Bill Williams River.

IMPLEMENTATION OF PLAN

Current Status. Following completion of the report "Proposed Water Management Plan for Alamo Lake and the Bill Williams River" (Bill Williams River Corridor Technical Committee, 1994), the Technical Committee requested each participating agency to provide formal letters of support for the report's recommendations. All agencies responded favorably to the Technical Committee recommendations. Coordination with the Corps' South Pacific Division and Office of the Chief of Engineers staff on how to proceed with implementation of the recommended operation produced the direction that congressional approval of a change in storage allocation was necessary to implement the recommended plan. The Corps then used the Technical Committee report as a basis for an Initial Appraisal Report requesting authorization and funding to proceed through the normal Corps planning process (reconnaissance and feasibility report). A 12-month duration Alamo Dam reconnaissance study officially started in July 1995. Arizona Game and Fish Department is the local sponsor for the study effort which is 100 percent federally funded. Public involvement in the Technical Committee process was deliberately limited in order to focus on the study effort. The Corps' has initiated a formal public involvement process, as well as coordination to insure full compliance with the National Environmental Policy Act. The feasibility phase will produce a decision document that provides a basis for Congressional action to reallocate Alamo Dam water conservation storage to threatened and endangered species, fish and wildlife, downstream riparian habitat, and recreation purposes.

Implementation Strategy. There is a need for flexibility in implementing the recommended operation plan. The enhancements to the various resource categories is the ultimate goal of the proposed change in operation. The water control plan must be written flexible enough to allow adjustments in operation based on biological and ecological monitoring studies that should be established along with any reoperation. The question of how well these resources respond to an anticipated improved operation can only be answered conclusively by establishing and maintaining monitoring studies.

SUMMARY AND CONCLUSION

A description has been presented of the Bill Williams River corridor and the water management conflicts that existed as a result of the many natural resource and project objectives dependent on a limited water resource. The resolution of these conflicts was successfully achieved through the cooperative efforts of the interagency ad-hoc Bill Williams River Corridor Technical Committee. The conflict resolution process was based on clearly defining, in a quantitative manner, the various agency goals and objectives. Hydrologic modeling of the river-reservoir system was then used to simulate a range of alternative Alamo Dam operation plans. Evaluation of the alternative plans was a matter of comparison against the quantitative measures already established for each objective. Although there was a long initial process of educating the Technical Committee participants in the important aspects of all the natural resource and project objectives, as well as hydrologic, institutional, and project constraints, it paid handsome dividends during the conclusion of the effort. Participants clearly understood why it was not possible to achieve optimum conditions for any single objective without significant impacts to other objectives. Their understanding of the total picture and the tradeoffs that are a part of any plan, enabled rapid agreement on selection of the recommended plan. Furthermore, that same understanding enabled them to educate and convince their respective agency managements to accept and support the recommended plan unanimously. The conflict resolution strategy followed by the Bill Williams River Corridor Technical Committee has the potential to successfully address other nature resource conflicts.

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PRESCRIPTIVE RESERVOIR MODEL APPLICATIONS FOR BILL WILLIAMS RIVER

by

Kenneth W. Kirby[1]

INTRODUCTION

Increasing demands for water, especially for environmental purposes, often result in conflict between different interests regarding reservoir system operation. Addressing these conflicts over water includes many facets such as establishing communication, quantifying objectives and evaluation criteria, and identifying and evaluating potential changes (USACE 1994). Frequently, some type of reservoir system model is necessary (but not sufficient) to find satisfactory solutions. This paper addresses the importance of quantifying objectives and analyzing alternatives to help find a workable compromise between those in conflict. These tasks are only a subset of conflict resolution activities, and usually much work is needed to reach the point in the process where the tools presented here can be useful.

This paper presents elements of a structured approach for applying prescriptive (optimization) and descriptive (simulation) models to help identify alternative operational strategies. As part of this process, a method to quantify objectives for different water uses without a complete economic analysis is presented. Quantification of each water use objective entails the adoption of a numerical scale to provide an indicator for measuring the effectiveness of alternative operational strategies. This indicator of effectiveness is necessary to analytically compare different operational strategies. The technique shown allows representation of water values through relative unit costs according to value categories set by the interest groups.

To demonstrate the potential for using this modeling approach Alamo Reservoir, Arizona is analyzed according to the procedures advocated. The advantages and difficulties of applying this optimization - simulation approach to help resolve conflict are discussed.

MODELING RESERVOIRS TO RESOLVE CONFLICT

Some tasks necessary to resolve conflict regarding water include: identifying stakeholders and decision makers, defining regional objectives and constraints of stakeholders and decision makers, identifying areas of conflict, evaluating current conditions, generating alternatives, and selecting alternatives. Computers and computer modeling now have an important role in providing information for the tasks of conflict resolution.

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The proposed modeling strategy presented in this paper uses both a prescriptive model and a descriptive model. The prescriptive model is used to generate and screen promising alternatives for mitigating conflict based on explicit objectives and the simulation model is used to test and refine promising alternatives from the prescriptive model results. This screening and refining technique is similar to that proposed by Jacoby and Loucks (1972).

Uncertainty and Objectives. Data used for modeling reservoir operation such as inflows, population estimates, water usage rates, and expected damage due to flooding are not certain. These uncertainties can have a major impact of water resource systems analysis in a physical, ecological, and economic sense. Although the analyst can model some uncertainties and explain their consequences using various indicators, one cannot eliminate uncertainty or even reduce its impact to the point of insignificance. Major sources of uncertainty will always be present (Loucks, *et al.* 1981).

This uncertainty, coupled with the possibility of unclear and often continuously evolving preferences by the public or specific interest groups, can make it difficult to choose one alternative over another. It is likely that the public (as represented by the decision makers) will be indifferent between several alternatives. At the same time, particular groups of individuals likely will express intense preferences regarding specific alternatives. One alternative will rarely qualify as a *best-compromise* solution (where all interests get what they desire). Rather, it is more reasonable to seek an alternative where all interest groups can be sufficiently *satisfied* to end the conflict.

PROPOSED MODELING STRATEGY

The proposed strategy consists of seven steps intended to produce a range of promising operational alternatives to be considered in the conflict resolution process (See Figure 1). This procedure is primarily an analytical tool to aid in *part* of the conflict resolution process. Although this process does not cover all aspects of conflict resolution, the structured analytical strategy can help focus activities or provide a common point of reference for the stakeholders in conflict. This focus can help start the resolution process and help keep it moving.

Overall, the strategy applies a prescriptive model to screen alternatives, and then uses a simulation model to test and refine the more promising alternatives. It is important to understand the intent of this approach and its impacts on the notion of optimality. Although the procedure uses a

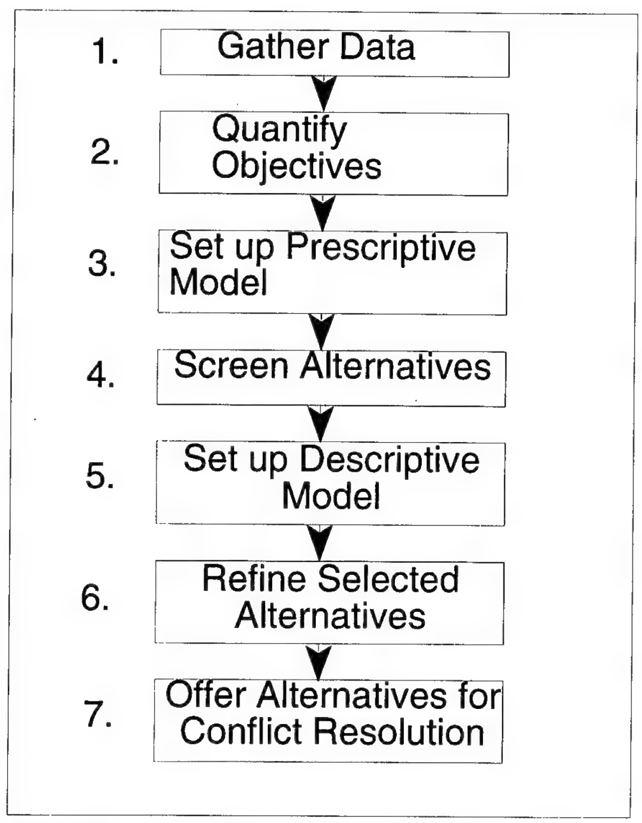

Figure 1. Steps in Proposed Modeling Strategy

prescriptive model, there is no claim of producing a "global optimum" solution for meeting conflicting demands on multiple purpose reservoirs. In fact, the complex multiobjective nature of this problem coupled with the simplifications required to solve these problems analytically, render the possibility of discovering an analytical "global optimum" impossible (Cohon 1978; Jacoby & Loucks 1972). Nonetheless, the analytical effort can still be worthwhile for conflict resolution efforts. Used together, prescriptive and simulation models can efficiently produce a range of viable alternatives to help those in conflict reach an acceptable compromise.

This paper concentrates on Step 2 in the process: "Quantify Objectives."

Quantify Objectives. Quantifying values of different water uses is essential for prescriptive modeling, and is usually the most difficult step. Previous studies performed by the Hydrologic Engineering Center (HEC) using prescriptive models employed economic objective functions (USACE 1991a; 1991b). Economists worked extensively to assign monetary values for every use being considered at each reservoir and related river reach. This approach is effective for traditional uses such as flood control, hydropower, irrigation, and recreation where widely accepted economic methods exist. However, economic valuation is more controversial for environmental objectives such as endangered species preservation or riparian habitat restoration. Methods to economically value environmental performance have proven elusive (Smith 1989). The availability of economic expertise can also limit economic valuation of uses for small reservoir systems. For the large reservoir systems (Missouri and Columbia) previously studied using the HEC Prescriptive Reservoir Model (HEC-PRM), experienced economists familiar with the system were available to perform this monumental task (USACE 1993).

Since prescriptive models rely on mathematical programming techniques, water use values must be expressed as mathematical functions with particular characteristics. Typically, the objective functions used with the model must be convex. Obviously, complex value functions for water uses cannot be explained exactly by simple mathematical functions. However, this paper assumes that all that is required in this context is to establish a function that permits *reasonable* comparisons between uses. The following section summarizes a systematic procedure for developing value functions that does not require economic analysis. The prescriptive model used for the case study (HEC-PRM) requires that water use values be represented via penalty functions. Penalty functions are essentially inverse value functions; the point of maximum value (utility) can also be expressed as the minimum penalty (cost). In subsequent discussions, the quantitative specification of water use values are expressed as penalty functions. The technique for creating a numerical representation of water values is referred to as the Relative Unit Cost (RUC) Method. Unlike the economic approach of constructing penalty functions (USACE 1993), penalty functions constructed using the RUC Method are relative rather than absolute. Penalty values computed for a given magnitude of flow or storage have meaning only when compared to other penalties for the same system. Penalties derived with the RUC Method are sufficient for comparing water uses on a reservoir system, but the penalty values cannot be used to make comparisons with other reservoir systems. Figure 2 diagrams the steps necessary to implement the Relative Unit Cost Method. The diagram shows the process is intended to be done iteratively until the penalty functions represent the actual water

use values with acceptable accuracy. The level of required accuracy must be determined by the analyst with feedback from the advocacy groups.

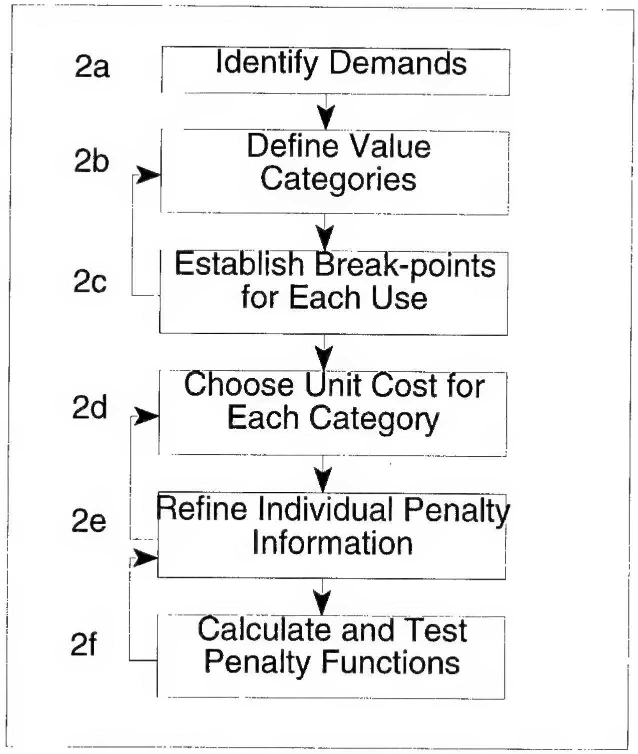

Figure 2. Steps in Relative Unit Cost Method

<u>Step 2a: Identify Demands on the System</u>. The first step requires identification of the demand for each water use served by the reservoir system. Along with the demands, the groups advocating each use also should be identified. Once the demands and their advocates are identified, common value definitions need to be established to allow the various groups to communicate meaningfully with the analyst.

<u>Step 2b: Define Value Categories for Each Use</u>. Values for each use must be associated with a physical aspect (storage or flow) of the reservoir system to reevaluate reservoir operation. Utility gained from reservoir operation needs to be defined over the range of possible storages or flows for each use. To simplify quantification of value realized by each use from alternative reservoir operations, the benefits can be divided into generalized *value categories*. These value categories refer to ranges of advocacy group general preferences. By determining which value category different magnitudes of storage and flow correspond, the range of storages and flows can be divided into *value regions*. These value regions refer to that set of storages or flows that produce benefits for a particular use that fall within a given value category (or advocate preference). The number of categories necessary for sufficient resolution of value definition may vary between systems, but three categories seems a reasonable place to start. Figure 3 shows an example of how benefits for one particular use related to reservoir storage could be divided into five regions according to three value categories: Ideal, Acceptable, and Adverse. These general value categories provide advocacy groups with a common framework to specify their goals in terms of physical reservoir operational parameters and a few general levels of preference.

<u>Step 2c: Identify Storage or Flow "Break-Points"</u>. Specific magnitudes of flow and storage that delineate the value regions for each use need to be identified. For the RUC Method, the flow or storage quantities that define the value region boundaries are called *value break-points*. To illustrate how value categories and break-points are used to help quantify objectives, consider recreation on a multiple purpose reservoir. The aim is to find those points in the operation of the reservoir where the quality or value of lake recreation changes significantly as represented by the chosen value categories. Recreation on the reservoir (as opposed to the stream) depends primarily on storage levels. As the amount of water stored in the reservoir changes, the elevation of the lake surface changes. Since much of the recreation activity on the

lake depends on facilities around the lake perimeter (boat ramps, docks, etc.) the level of the lake surface is a key factor of lake recreational value. Therefore, a good way to establish value break-points for reservoir recreation would be to determine how lake surface elevations impact the use of access structures such as boat ramps. Table 1 lists elevations (storages) that delineate five value regions based on three value categories. The value categories were defined to mean:

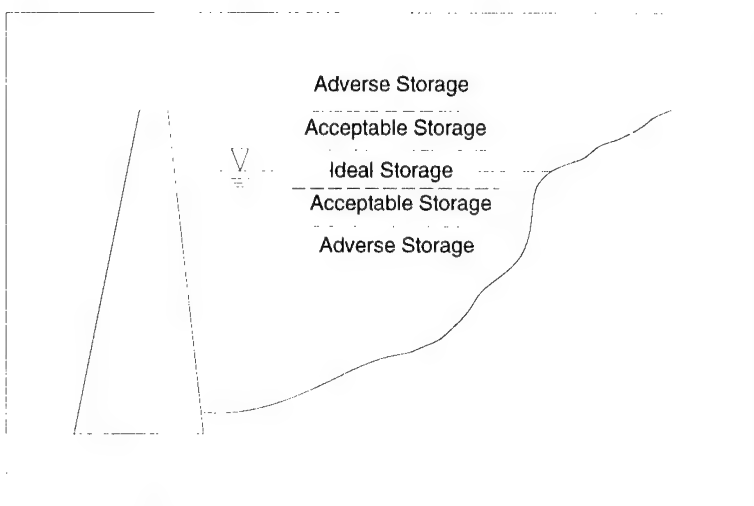

Figure 3. Example Value Regions for Reservoir Storage

- *Ideal* -- the range of storages or flows that provides the most utility for the advocated use (The advocacy group is content).
- *Acceptable* -- the range of storages or flows that provides moderate utility for the advocated use (The advocacy group can tolerate the level of benefits produced but would prefer to operate in the *Ideal* region).
- *Adverse* -- the range of storages or flows that reduces benefits for the advocated water use by unacceptable amounts (The advocacy group strongly opposes operation in this region for long periods).

Based on these categories and their definitions, the reservoir recreation advocacy group can identify reservoir levels that delineate the value regions. For the hypothetical case (Table 1), consider the following scenario:

Table 1. Example Break-points for Reservoir Recreation Use

Value Region	Storage Range (KAF)	Elevation Range (ft)
Adverse	239.7 to 1451.3	1,144 to 1,265
Acceptable	160.5 to 239.7	1,125 to 1,144
Ideal	124.8 to 160.5	1,115 to 1,125
Acceptable	65.5 to 124.8	1,094 to 1,115
Adverse	0 to 65.5	990 to 1,094

- The *Ideal* storage region is between 124.8 to 160.5 KAF due to the accessibility of two well developed boat ramps and an unpaved boat launching access. This facilitates easy access to the popular water sports areas.

- The *Acceptable* storage regions include 65.5 to 124.8 and 160.5 to 239.7 KAF. As the storage drops below 124.8 KAF or rises above 160.5 KAF, access to one of the developed boat ramps is hindered. This causes a reduction in watercraft access to the lake and therefore decreases recreational use.

- The *Adverse* storage region could represent inaccessibility of all developed boat ramps.

Once value regions have been identified, the concept of unit cost can be applied to calculate penalty values for all possible storages or flows (Step 2d).

This part of the model formulation can be both time consuming and costly. Gathering data to identify how reservoir operation impacts each desired use can require a great deal of work on the part of the advocacy groups (since the advocacy groups and others may not know how reservoir operation affects their desired use). However, if the qualitative definitions are not done adequately, the penalty functions will not be useful. (This is true for economically based penalty functions as well.)

Note: Defining value categories (Step 2b) and identifying break-points (Step 2c) are interrelated. (Both steps serve to define the value regions.) For some cases, the process may be easier if critical value break-points are identified for each use and then value categories are designated later according to the number of break-points.

***Step 2d: Apply Unit Cost Strategy for Value Categories*.** Identifying the value regions (ranges of physical parameters with constant value) for each use provides only half of the information necessary for a mathematical value function. The analyst must now supplement the qualitative information with quantitative value information. When using economic techniques for this part of penalty function development, economists typically determine the maximum possible economic benefit when the reservoir is in the Ideal region and then estimate the cost (revenue lost) for operating the reservoir at points outside this region. Non-economic penalty functions can be constructed following a similar strategy. A systematic method using relative unit costs can be used to create penalty values at points throughout the defined value regions.

Two questions must be answered to formulate numerical value functions for use with an prescriptive model:

1) How do benefits (penalties) change for each use as the reservoir system operation moves away from the Ideal value region?

2) How do the benefits (penalties) from each water use compare to one another?

To answer the first question, the penalty for the *Ideal* region must be defined. Since the Ideal region represents the best value that can be realized for the use being considered, both the unit cost and the actual cost are zero within the *Ideal* region. In fact, the definition of value categories infers that the utility or benefit for a particular use is constant over each value region. The objective function must be convex in order to find an optimum solution with linear

programming. If the analyst wants to take advantage of linear programming prescriptive models, the value function must be edited to an acceptable form.

One way to avoid some of the problems stemming from convexity is to represent the penalty function by specifying a slope (unit cost) for each value region rather than a specific penalty value. This approach produces a convex function directly for most uses and reduces the amount of "adjustments" necessary to fulfill convexity requirements. However, a disadvantage of specifying unit costs directly is that the resulting penalty quantities will not necessarily be equal at the boundaries of similar value regions (such as the two boundaries between *Acceptable* and *Adverse* in Figure 4). This difference in penalty magnitude for the value region boundaries will be most pronounced for uses where the value regions are highly asymmetrical about the *Ideal* region.

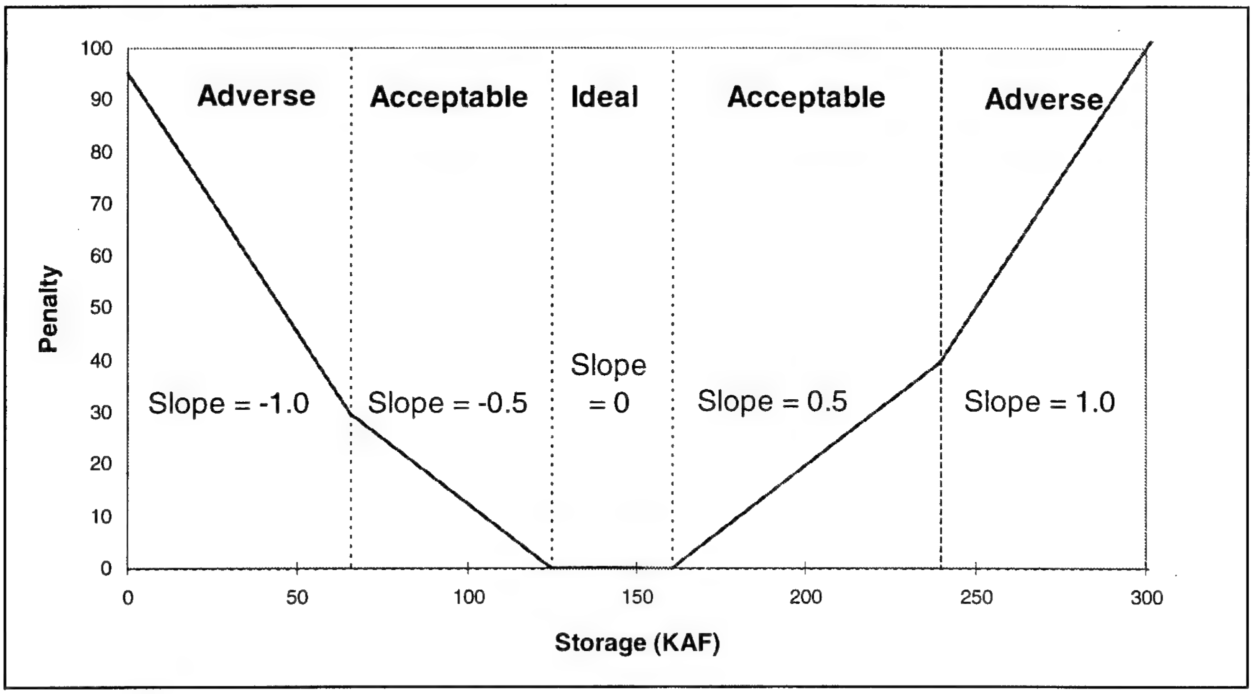

Figure 4. Plot of Penalty Using Unit Costs of 0, 0.5 and 1.0 for Value Categories

Since the RUC method is not intended to produce absolute penalty values (such as economic values), the magnitude of unit costs for a value category is unimportant except in relation to the magnitude of unit costs for other value categories and uses. This premise is key to the success of the RUC Method. The analyst can create penalty functions with the information gathered by defining meaningful unit cost *ratios* between value categories and uses. At this point in the process, the unit costs for the same value category among different water uses is initially assumed to be equal. This assumption is made to facilitate the initial penalty definition (its validity will be discussed later). The analyst must now choose magnitudes for the unit cost for each general value category. When trying to choose initial magnitudes it is best to keep the formulation as simple as possible. Perhaps the easiest way to explain this process is through example.

Figure 3 shows that the range of possible storages for the hypothetical reservoir are divided into five distinct value regions specific to recreation benefits. The analyst now tries to represent how the recreational benefits change when the reservoir is operated in these different regions. For the first attempt at describing the recreation penalty function for the hypothetical reservoir (data in Table 1 and Figure 3), unit costs are chosen to be 0.5 while in the Acceptable region and 1.0 while in the Adverse region. (By definition the unit cost is zero everywhere in the *Ideal* region.) Figure 4 illustrates the resultant penalty function when calculated for the chosen unit costs. These unit cost magnitudes can be interpreted to mean "As reservoir storage deviates outside the Ideal region into the Acceptable region a penalty of 0.5 units is realized for each KAF of change. If reservoir storage deviates from the Ideal region sufficiently to reach the Adverse region, each KAF deviation beyond the Acceptable region adds 1.0 unit to the penalty. Further interpretation of these chosen unit cost magnitudes implies that the penalty assessed within the Adverse region occurs at twice the rate as when in the Acceptable region. This ratio of unit costs between value regions needs to be established in cooperation with each advocacy group. Since the resulting penalty functions are used only to compare different alternatives through a mathematical programming algorithm, the ratios do not need to be exact. Instead, the ratio relationships need only be accepted as reasonable by the interest groups.

Again, the choice of unit cost values are only important in relation to one another. For instance, in the previous example, unit costs of 1.0 and 2.0 (Ratio = ½) could be used in place of 0.5 and 1.0 (Ratio = ½) with no change in functionality. However, if values of 0.5 and 0.75 (Ratio = 1/1.5) are used, the implication is significantly different. The ratio of unit costs needs to be selected to reasonably represent the actual change in utility realized as reservoir conditions change. For simplicity, the value categories should be chosen so that one set of unit costs can be applied for each use. In other words, if unit costs of 0.5 and 1.0 are used to calculate penalty values while in the Acceptable and Adverse regions for recreation, the same unit costs should be applied for the other uses (such as flood control or conservation) on the reservoir. Obviously, the break-points that delineate where the value regions start and stop for each use will be different, but the unit cost for each region should be kept consistent between uses (under the initial assumption that all uses are of equal value).

Step 2e: Refine Penalty Information for Each Water Use. The previous exercises yield a "rough" penalty formulation (as shown in Figure 4) for each water use being considered. Now the penalty functions should be refined by addressing two issues:

1. The region of zero slope in the *Ideal* region, and
2. Important value changes for some uses not represented by the broader value regions.

Penalty functions with a segment of zero slope can lead to instability in the numerical methods for problem solution and should be avoided. Fortunately, this problem is not difficult to avoid. In reality, water users are seldom truly indifferent regarding a range of operational parameters even though all points within that range yield the same real benefits. Therefore, the task at hand is to determine which *point* in the Ideal region the advocacy group would prefer if given a choice.

One potential pitfall with the Relative Unit Cost Method stems from biasing and must be carefully avoided. Because the method utilizes unit costs to define penalty values for differing uses instead of actual costs, the implication of penalty functions can be misleading between uses. The key area of concern arises when comparing storage related penalties and flow related penalties. Since potential changes in flow tend to be small when compared to the range of possible reservoir storages, biases placed on storage related penalties can actually overshadow resultant penalty values for flow related issues. Therefore, the analyst must insure that the maximum possible penalty due to "biasing" is always smaller than the maximum possible penalty for all other uses within that same value category.

Step 2f: Calculate and Test Penalty Functions. The final step in the RUC Method involves calculating actual penalty values at all break-points for each individual use. Since the penalties are described by constant unit costs between these points, penalty values at the break-points are sufficient to describe the entire penalty function. Also, because the penalty functions are constructed using general information, each penalty function representing the individual uses should be tested. Then to solve for system operation considering all uses, the analyst must combine the individual use penalty functions that apply to the same reservoir or river reach. This combination of individual penalty functions is called a *composite* penalty function.

Once break-points (independent variable) and unit cost magnitudes (slope) have been defined for all uses, calculation of the penalty values (dependant variable) is straightforward. Nonetheless, these simple calculations become quite laborious when repeated many times. The work necessary to create composite penalty functions can be particularly time consuming. To make this process less onerous and more reliable, a computerized pre-processor utilizing a graphical-user interface was created to aid in constructing individual and composite penalty functions.

After penalty functions are calculated for each water use, they should be tested. The recommended test procedure involves running HEC-PRM for each use as if it were the only demand on reservoir operation. The results for each run should represent the mathematically "optimal" reservoir system operation for that use over the analysis period. The analyst can then scrutinize the results to determine if the penalty functions for that use produce results consistent with expectations based on the verbal objective. For example, if the model is run for the hypothetical recreation scenario used before, the resulting reservoir storage levels should fall in the *Ideal* region a significant amount of the time. If the results show significant occurrences where the reservoir storage is consistently above the *Ideal* region the analyst could deduce that the penalty functions are probably not representing the stated objective adequately. Since the prescriptive model is operating for only one purpose, resulting operations should be in the *Ideal* region unless there is too much or too little water introduced into the system to allow that to occur. Similarly, if analyzed for an objective that specifies an *Ideal* release region, and the results seldom match that region, the penalty functions for that objective should be reconsidered.

Testing the penalty functions for each use in this manner produces another benefit. Once the analyst believes the penalty function adequately represents the stated objective, the HEC-PRM results for that purpose indicate the highest benefit that can be obtained for a particular use. These results can give the interest groups a good indication of the best they can hope for with

respect to their advocated use since HEC-PRM made operating decisions based exclusively for that demand. The results can also indicate how the different demands influence reservoir operation, quickly pointing out similarities and conflicts.

After testing and refining the unit cost specifications for each water use, the designation of relative value between the water uses should be revisited.

Summary of Modeling Strategy. The proposed modeling strategy offers a systematic method to develop, screen, and evaluate reservoir operational alternatives to help solve conflict over water resources. The method takes advantage of an prescriptive model for screening and a simulation model for testing and refining alternatives. Prescriptive models require numerical representation of value for all water uses. Historically, most of these quantitative value functions have been formed using economic analysis. However, economic analysis is not always feasible for all water uses. Therefore, a structured method to produce relative value functions was presented. This method provides an approximate representation of advocacy group preference towards specific modes of reservoir operation. These approximate value functions allow the analyst to benefit from the prescriptive model's screening capability to reduce the number of more detailed simulations needed. The series of steps proposed were used to perform the following case study.

CASE STUDY - ALAMO LAKE, ARIZONA

The operation of Alamo Lake, Arizona was evaluated to demonstrate the proposed modeling strategy and test the Relative Unit Cost Method. Alamo Lake is a multiple purpose reservoir owned and operated by the U.S. Army Corps of Engineers. Alamo Lake is located in La Paz and Mojave Counties in Arizona on the Bill Williams River approximately 40 river miles upstream of the confluence with the Colorado River. The reservoir has a maximum capacity of 1,451,300 acre-feet and serves a gross drainage area of 4,770 square miles with a mean annual runoff of 113,300 KAF. Average annual precipitation for the Bill Williams River Basin is 13 inches and average annual pan evaporation is 65 inches.

During the late 1980's, agencies responsible for managing the Bill Williams River and Alamo Dam and Reservoir experienced increasing conflict between their individual missions and perspectives. Much of the disagreement stemmed from how the Corps was operating the water conservation pool at Alamo Lake. In August of 1990 the agencies instituted an interagency planning team to develop a comprehensive water resource management plan for the Bill Williams River corridor. Over the past several years the Bill Williams River Corridor Technical Committee (BWRCTC) thoroughly defined the competing demands related to reservoir operation. The committee then used a descriptive model (HEC-5; USACE 1982) to evaluate alternative operational strategies intended to meet demands more effectively. The information gathered during the BWRCTC study was used to apply the prescriptive-simulation strategy.

Step 1: Gather Data. The first part of the modeling process involves gathering relevant data. The BWRCTC gathered the necessary data (hydrology, water management objectives, and system constraints). The hydrology and system constraints were provided by the Los Angeles

District U.S. Army Corps of Engineers Office. The water management objectives were defined in the BWRCTC report (1994).

The following list provides a description of the water management objectives (BWRCTC 1994):

- *Flood Control* -- The dam was authorized to provide flood control for lower Colorado River communities downstream from Parker Dam (Lake Havasu), and protect property along the Bill Williams River corridor. Alamo Dam is operated in conjunction with the U.S. Bureau of Reclamation dams on the Colorado River to reduce flood related damage.
- *Water Conservation and Supply* -- The entire water supply in the Bill Williams River (before reaching Lake Havasu) is entitled solely to Arizona. Bill Williams River flows that reach the Colorado River are allocated in a manner consistent with the "Law of the River" including the U.S. Supreme Court Decree in *Arizona v. California* of March 1964. To date, the Corps has not contracted with a water supply user for supply and conservation storage. The conservation pool has been used only for short-term storage of water, which has been released to Lake Havasu.
- *Recreation* -- The recreation pool was established immediately below the water conservation pool. The Arizona Game and Fish Department currently holds water rights for 25,000 acre-feet in the recreation pool. These rights are for fish, wildlife, and recreational purposes. The Arizona State Parks Department operate and maintain boat launching ramps, campgrounds, and appurtenant structures.
- *Fishery* -- Arizona Game and Fish has established a lake bass fishery. The productivity of the fishery is most directly connected to fluctuations in lake levels during the spawning and growing season.
- *Endangered Species* -- Two pair of Southern Bald Eagles, a Federally listed endangered species, have been nesting around Alamo Lake since the early 1980's. In 1988 the U.S. Fish and Wildlife Service requested that the Corps maintain a minimum water surface elevation of 1,100 feet at Alamo Lake to ensure sufficient forage area for the eagles. The request was in accordance with the National Environmental Policy Act and the Endangered Species Act.
- *Wildlife Habitat* -- The Bill Williams River Corridor includes a National Wildlife Area and is home to various neo-tropical migratory birds and several threatened or endangered species. The wildlife habitat is most dependant on the vitality of the riparian habitat.
- *Riparian Habitat* -- The riparian habitat along the Bill Williams River contains the last extensive native cottonwood tree stands in Arizona. The U.S. Fish and Wildlife Service believes that a significant portion of the cottonwood trees have been destroyed due to the pattern of past Alamo Dam releases.

Step 2: Quantify Objectives. Subcommittees of the Bill Williams River Corridor Technical Committee compiled separate reports with verbal descriptions of each water management objective. The information is well documented (BWRCTC 1994). These reports also detail break-points for storage and flow established for each use according to three value categories. Based on the information in the BWRCTC reports, penalty functions were defined for each use following the Relative Unit Cost Method. These penalties were tested as proposed in the RUC Method description by running HEC-PRM exclusively for each objective.

Furthermore, the HEC-PRM results were compared for each water use to discern how the advocate groups requests translated into reservoir operation. This type of evaluation provides some interesting insights into how different demands can impact reservoir operation. For example, the resulting operation for riparian related use was particularly surprising. The stated goal of the BWRCTC Riparian Subcommittee is to:

> ... restore riparian resources downstream from Alamo Dam and maintain the cottonwood gallery forest at the upper end of Alamo Lake. The primary objectives for riparian resources in the Bill Williams River Corridor are 1) *to maintain both area (acreage) and structural diversity of existing vegetation stands dominated by native riparian species*, particularly cottonwood/willow stands, and 2) *to expand coverage and diversity of native riparian through natural recruitment.*

The subcommittee report also states "A properly functioning riparian ecosystem could be restored by implementing a flow regime that mimics the pattern of historic (pre-dam) flows." However, when the penalty functions for riparian habitat interests were developed to produce the flow patterns specified in the report, the HEC-PRM results actually produced a release pattern quite different than the "historic (pre-dam) flows". Figure 5 shows the resultant monthly release pattern for Alamo Reservoir when operated exclusively to meet the demands of riparian habitat support and restoration. The flow results from HEC-PRM shown in Figure 5 approximate the requested flow pattern for riparian habitat maintenance and restoration well, but actually bear little resemblance to the pre-dam flows. These types of discoveries can be valuable both for the analyst and the advocacy groups. HEC-PRM results give an idea of the best operation possible for each use (tempered by the simplifications required in forming convex penalty functions), and serve as a way to verify that the operational patterns requested by the advocacy groups produce the results they desire. The prescriptive results for each use also provide information to determine which demands conflict with one another. Figure 6 shows the storage time series determined to be optimal for each use. From this plot, it is clear that the fishery and recreation alternatives produce similar storage patterns. In contrast, the uses producing the most disparate storage patterns are the riparian habitat and flood control objectives. Figure 6 also shows that HEC-PRM utilizes nearly the entire range of reservoir storage (up to a maximum level specified by riparian interests) to produce a consistent and regular flow pattern (as seen in Figure 5). On the other hand, the flood control objective causes HEC-PRM to keep the reservoir as empty as possible (recognizing that a multiple purpose reservoir would probably never be completely empty) to allow attenuation of incoming flood peaks. This type of comparative information provides valuable insight regarding reservoir operation for multiple demands.

<u>Step 3: Set up Prescriptive Model</u>. HEC-PRM generates optimal monthly reservoir operations according to specified water use values (or penalty functions), input hydrology, constraints, and initial and ending conditions. The input hydrology used for HEC-PRM is a historical record spanning 103 years of monthly inflows (January 1890 - December 1993) obtained from the Los Angeles District U.S. Army Corps of Engineers Office. HEC-PRM was configured with the evaporation option using monthly evaporation rates provided by the L.A. District Office. Starting storage for each HEC-PRM run was set at 80.4 KAF to be consistent with the HEC-5 study conducted by the L.A. District Office. The only constraint added to the model was a minimum release of 10 cubic feet per second (cfs) required by Arizona water rights.

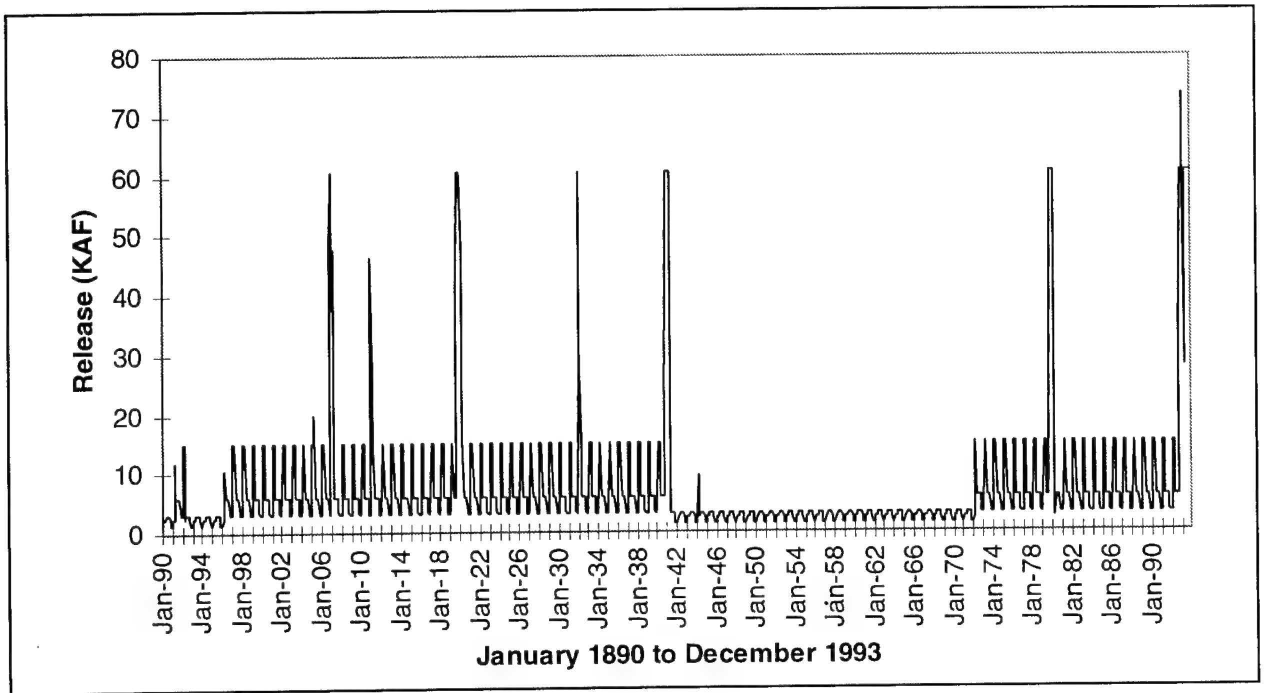

Figure 5. Monthly HEC-PRM Releases Based Strictly on Riparian Penalty Functions

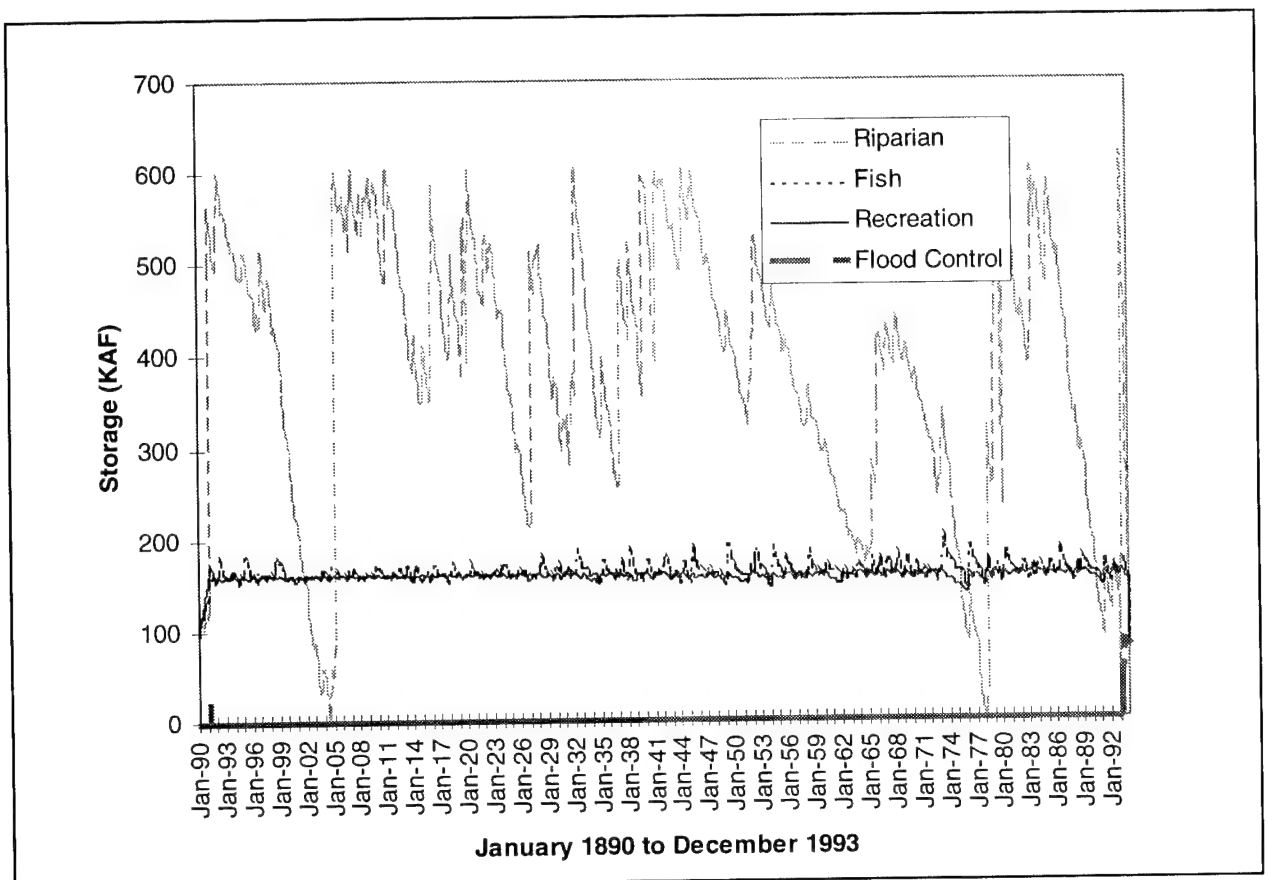

Figure 6. Comparison of Preferred Storages for Each Use

Due to simplifications required in formulating the problem for HEC-PRM, some specific objectives presented in the BWRCTC reports could not be represented. A primary example is the objective of limiting maximum daily fluctuations in lake level for fisheries. This objective could not be represented in HEC-PRM since the program can only consider monthly time steps. Another example is the objective to provide seasonal "flushing flows" to benefit the riparian habitat. These flows (intended to be high "pulse" flows that last for a few days) could not be explicitly represented in the monthly prescriptive model. These limitations were considered when inferring operating rules from the prescriptive results.

Step 4: Screen Alternatives. Information provided by the BWRCTC indicated that it was reasonable to consider all water management objectives to be equal. Since this single case was adequate to demonstrate how to apply the proposed modeling strategy and test the RUC Method, further multiobjective analyses were not included in this paper. Future research to develop support tools for applying the Weighting Method and Prior Assessment of Weights with HEC-PRM has been proposed. Since only one alternative was generated using HEC-PRM, the second phase of screening using yield and reliability information was not necessary at this step. Figure 7 displays the storage time series that HEC-PRM determined to be optimal for the specified hydrology, constraints, and objectives. These results are scrutinized further in the refinement stage.

Step 5: Set up Descriptive Model. To refine alternatives, a simulation model must be formulated to represent the system being studied. For this case study, Stella II © by High Performance Systems, inc. (1993) was used to perform the simulation analysis. This modeling package was chosen because it allows for very flexible operating rule construction. The hydrologic input for the simulation modeling consisted of 64 years of daily inflows obtained from the Los Angeles District Corps office.

Step 6: Refine Alternatives. To fully benefit from the prescriptive model, a set of operating rules that can reproduce an operational scheme similar to the one found in the HEC-PRM results should be formulated. In addition to the time series plots, descriptive statistics were generated for the storage and release results including percentiles and exceedance probabilities. Figure 8 shows percentiles of storage by month for HEC-PRM results based on the composite penalty function. This plot illustrates that HEC-PRM resultant monthly storages remain fairly constant throughout the year for most years (the trace of the 10th percentile and 90th percentile tend to be near the median for most months). From this, it appears that the operating rule should be set up to maintain a fairly constant storage level throughout the year. The percentile plots for HEC-PRM releases indicate that releases are very low most of the time, but during a few months of the year the releases can be quite high. Because the releases tend to be very small at least 75% of the time, the previous deduction that the operating rule should be geared towards maintaining a set reservoir storage level is strengthened. Traditionally, release decisions are made according to changes in storage, or according to which authorized pool the reservoir is in. This approach could not be expected to work well if the goal is to maintain a target level. To verify this presumption, the HEC-PRM results were analyzed using time series analysis methods and scatter plots. Cross-correlation tests indicated that there is little correlation between changes in release and changes in storage but there is significant correlation between changes in release and changes in inflow. Scatter plots also indicate that there is little correlation between release and storage

but there is noticeable correlation between release and inflow. Therefore, the first operating rule tested in the simulation model was designed to make release decisions based on a monthly target storage and current inflows. This rule form was tested first at a monthly time step. After the monthly rule was deemed satisfactory, the rule was converted and refined for a daily time step.

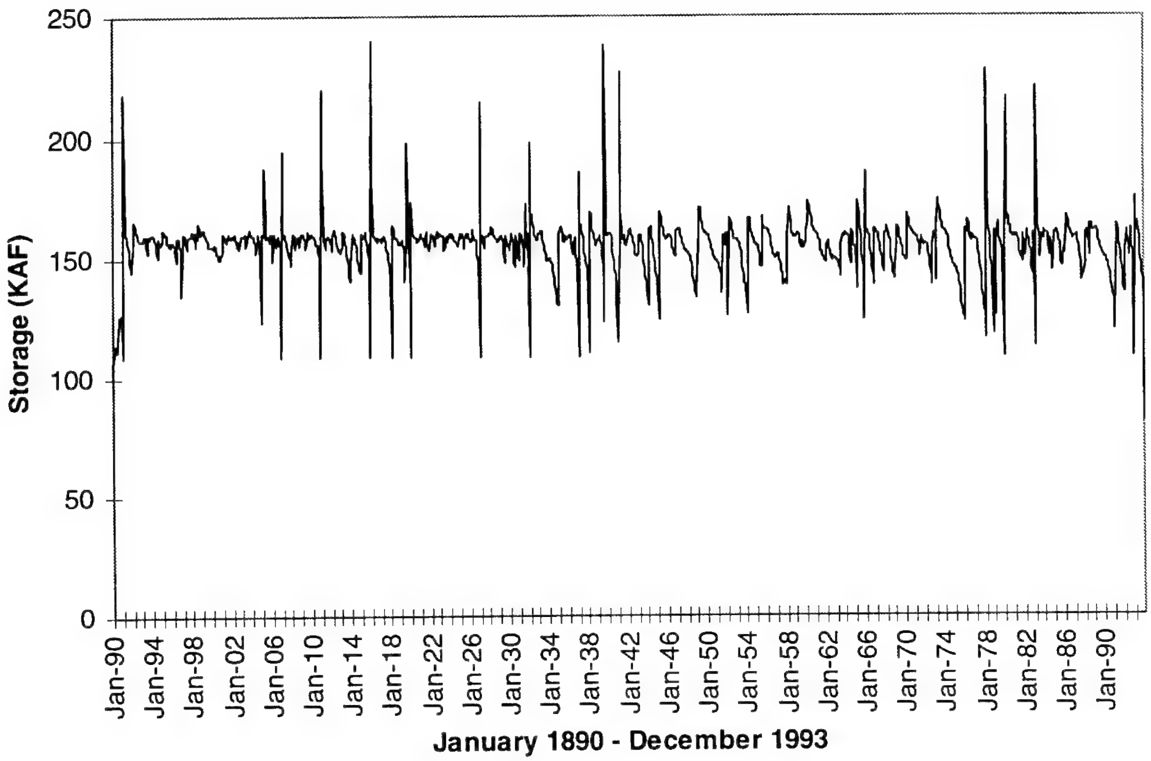

Figure 7. HEC-PRM Storage Time Series for Composite Penalty Function

<u>Step 7: Offer Alternatives for Conflict Resolution</u>. For most cases, the analyst would have results for several alternatives to present to the advocacy groups. The analyst could provide information in the graphical forms shown above, along with yield and reliability information. For this paper, only one alternative was analyzed fully and it is compared to the results of a previous study performed by the Los Angeles District U.S. Army Corps of Engineers using simulation alone.

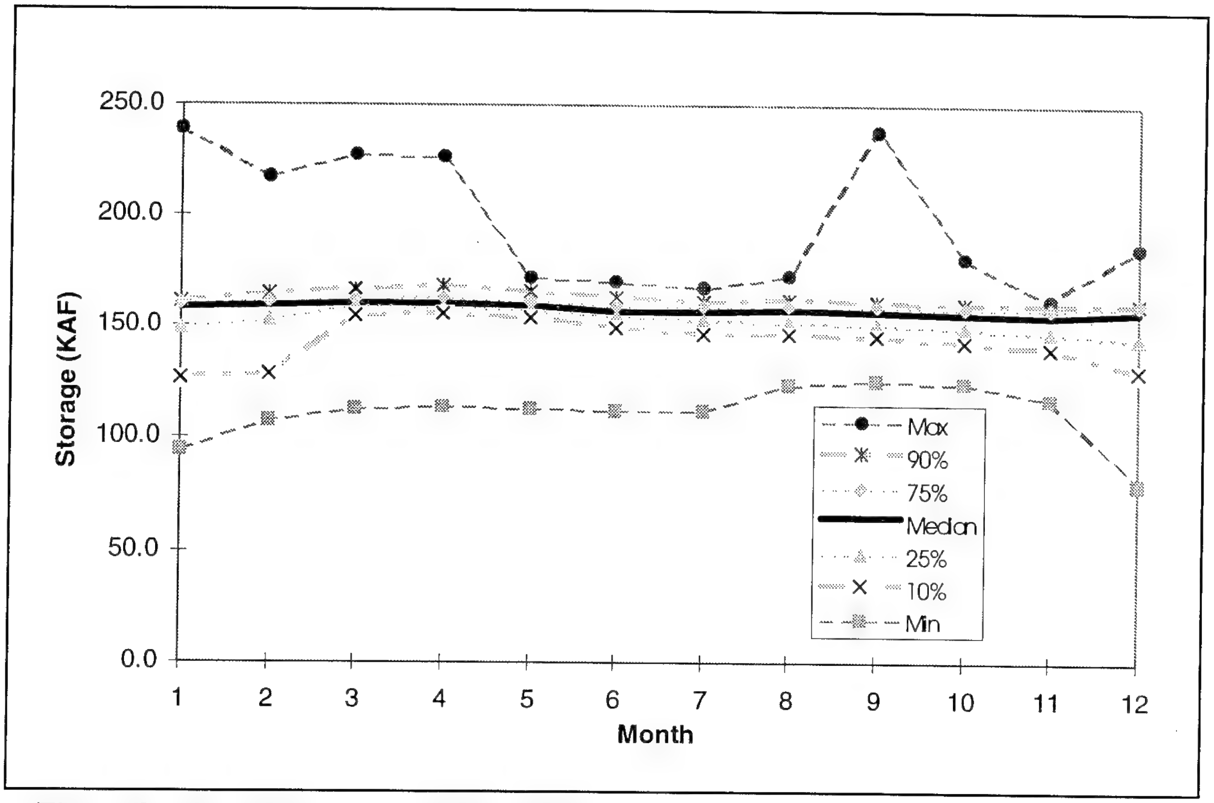

Figure 8. Percentile Plots for HEC-PRM Alamo Storage Results for Composite Penalty

COMPARISON OF RESULTS

As part of the conflict resolution efforts of the BWRCTC, the Los Angeles District U.S. Army Corps of Engineers performed a modeling study of Alamo Reservoir and the Bill Williams River using a simulation model (HEC-5). The report (BWRTC 1994) presents results for ten different main alternatives (two represent past and present operations) and four variations of the preferred main alternative. The alternatives were evaluated according to a series of yield and reliability criteria. The simulation of the operating rule derived from HEC-PRM was compared to the simulation A1125WOD performed by the Los Angeles District U.S. Army Corps of Engineers Office. The combined approach yielded better results for all storage related objectives. The riparian flow objectives "suffered" the most under the prescribed operation. (Almost 50% of the entire penalty over the period of record occurred from the riparian flow penalty.) This suggests that the riparian objective is most in conflict with the other objectives that prefer similar operational patterns. This type of information can be very useful when trying to produce a workable solution to end conflict.

CONCLUSIONS

An analytical reevaluation of reservoir system operation can provide useful information to aid in resolving conflict over water use. The proposed modeling strategy using a prescriptive model to screen alternatives and a simulation model to refine and test operational alternatives can

be an effective way to discover innovative strategies to more closely meet conflicting demands. By using the prescriptive model to screen alternatives, the simulation modeling can be more focused and efficient. Although this modeling strategy does not address all aspects of conflict resolution activities, it can help groups start communicating through the identification of demands and quantification of objectives. This allows groups to discuss and address specific conflicts instead of vaguely perceived problems. Furthermore, the systematic procedure for developing and evaluating operational alternatives can help advocacy groups sort through the myriad of data necessary to understand reservoir system operation. Hopefully, the modeling results will provide a viable range of alternatives to allow the groups in conflict find a satisfactory operation plan to end the conflict.

One of the problems encountered when trying to apply this type of approach for reservoir systems today is the difficulty in quantifying objectives for environmentally related uses. The Relative Unit Cost Method presented in this paper helps mitigate this problem. The RUC Method allows the use of prescriptive models to analyze reservoir systems even where economically based penalties are not practical. Even if most water management objectives can be accurately represented using economic techniques, the RUC Method can still be used to quantify those objectives that cannot be suitably represented using economic techniques. The value functions produced from both methods can then be used in conjunction with multiobjective programming techniques to generate promising alternatives. One of the primary advantages to the RUC Method is its relative simplicity and somewhat intuitive formulation. The method allows a practitioner to construct water use value functions based on verbal descriptions of goals provided by interest groups. One possible disadvantage of the RUC Method is the dependence upon broad statements of preference to build specific value functions. Also, since the method assigns magnitudes of unit costs for value regions instead of definitive penalty values for specific magnitudes of reservoir storage or release, the effectiveness of the penalty function must be tested by comparing prescriptive results to expected operational patterns based on the verbal water management objective. Subtle errors in the value functions may be difficult to discover through this testing method. The possibility of these errors coupled with the broad preference statements makes it possible that the prescriptive results do not accurately approximate the noninferiority set of solutions. However, due to the complex nature of multipurpose, multiple reservoir systems, it is likely that even with these potential errors, the combined procedure will be more efficient and effective than simulation studies alone.

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THE ACT/ACF COMPREHENSIVE STUDY
A CONSENSUS APPROACH TO WATER RESOURCES PLANNING

by

John Keith Graham[1]

INTRODUCTION

On January 3, 1992, the Governors of Alabama, Florida and Georgia and the Assistant Secretary of the Army (Civil Works) jointly signed a Memorandum of Agreement (MOA) which culminated approximately 18 months of intensive water resources negotiations. The negotiations were precipitated by a lawsuit filed by the State of Alabama against the U.S. Army Corps of Engineers (Corps) over proposed water supply reallocations in three Corps reservoirs within the Alabama-Coosa-Tallapoosa (ACT) and the Apalachicola-Chattahoochee-Flint (ACF) River Basins. The signing of the MOA officially initiated the ACT/ACF Comprehensive Study (the Comprehensive Study) of water resources within the basins. This paper will trace the background events leading to the Comprehensive Study and will describe its major aspects: objectives, management structure, content and status.

THE BASINS

The ACT Basin. The ACT River Basin, shown in Figure 1, extends about 320 miles from northwest Georgia across Alabama to near the southwest corner of the state. The total area of the drainage basin is 22,800 square miles. The Coosa River flows southwesterly from Georgia into Alabama where it joins the Tallapoosa River near Montgomery, Alabama to form the Alabama River. The Coosa River is highly developed with both Federal and private dams operated by the Corps of Engineers and Alabama Power Company. The Coosa River is fed by a number of smaller rivers in Georgia, two of which are the sites of large Corps reservoirs: Carters Lake near the headwaters of the Coosawattee River and Lake Allatoona on the Etowah River.

The Tallapoosa River begins in Georgia about 40 miles west of Atlanta and flows southwesterly through hilly terrain for about 45 miles before entering Alabama. After leaving Georgia, it continues to flow southwesterly for about 190 miles to its junction with the Coosa River. Four Alabama Power Company dams form lakes for about 33 miles along its course.

The Alabama River meanders southwesterly from its source at the confluence of the Coosa and Tallapoosa rivers near Montgomery, Alabama for about 315 miles to its junction with the Tombigbee River near Mobile, Alabama. Three Corps locks and dams create a series of lakes extending from near Claiborne, about 82 miles above the mouth, to the vicinity of Montgomery on the Coosa River.

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<u>The ACF Basin</u>. The ACF River Basin drains an area of 19,600 square miles, of which 8,770 square miles lie along the Chattahoochee arm and 8,460 square miles along the Flint River arm, with the remaining 2,370 square miles along the Apalachicola River below the confluence of the Chattahoochee and Flint rivers. The Chattahoochee River flows southwesterly from the Blue Ridge Mountains in northeast Georgia for 120 miles, then southerly for 200 miles, forming the boundary between Georgia and Alabama and between Georgia and a small portion of Florida. The length of the main stem of the Chattahoochee River is 320 miles.

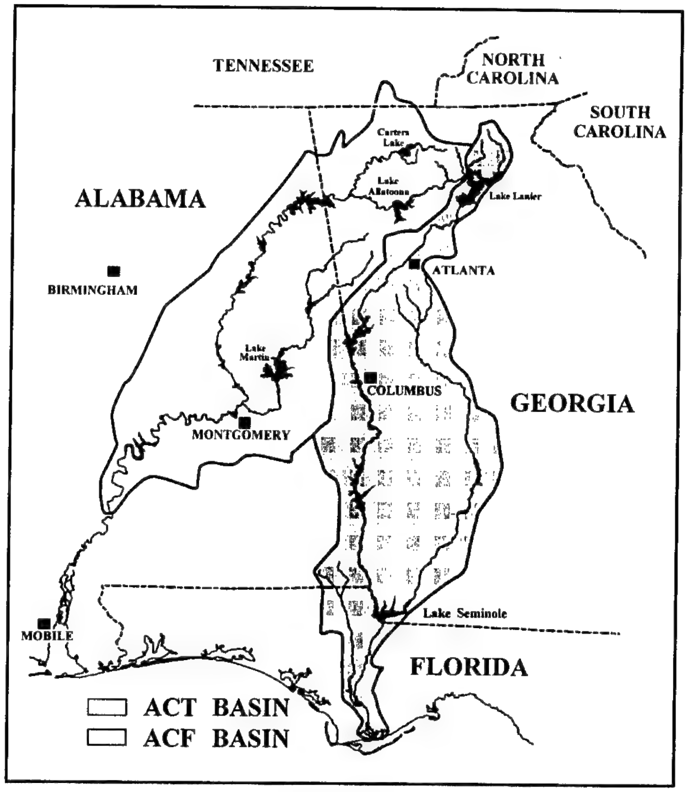

Figure 1

The Flint River originates immediately south of Atlanta, Georgia. It flows southerly in a wide eastward arc into the upper Coastal Plain and terminates in Lake Seminole at the juncture of the Chattahoochee and Apalachicola rivers. Two existing privately owned reservoirs along the Flint River have very little storage capacity and are operated generally as run-of-the-river reservoirs. The length of the main stem of the Flint River is 349 miles.

The Apalachicola River flows southerly across northwest Florida from the vicinity of the Georgia line to the Gulf of Mexico. It is formed by the junction of the Chattahoochee and Flint Rivers in the southwest corner of Georgia and terminates in Apalachicola Bay in northwest Florida.

BACKGROUND

<u>General</u>. In early September 1897, three steamboats loaded with cotton ran aground in the Chattahoochee River about 30 miles south of Columbus, Georgia. The *Columbus Enquirer Sun* reported on September 29, 1897, "The oldest inhabitant cannot remember a time when the Chattahoochee was as low as it is now." Columbus citizens believed the low water was caused by the fact that upstream Atlanta had constructed a water system that diverted seven million gallons a day from the Chattahoochee. Some four million gallons was used for domestic purposes and three million for flushing her sewers. The *Columbus Enquirer Sun* argued, "This thing is already becoming quite a serious matter with us and it is high time some steps were being taken to see what can be done about it."[2]

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[2] *Perilous Journeys: A History of Steamboating on the Chattahoochee, Apalachicola, and Flint Rivers, 1828-1928*, Mueller.

More recently, a series of droughts occurred in the basins during the years 1981, 1986 and 1988. Each of these droughts resulted in significant effects on hydropower production, navigation, municipal and industrial water supplies, and other water uses. The 1981 drought saw record low pool levels, 20 feet below normal, in Lake Lanier, severely restricting recreation use. During the 1986 and 1988 droughts, numerous municipal and industrial users implemented for the first time both voluntary and mandatory water conservation measures. This sequence of droughts created a keen awareness of the finite quantity of water resources in the basins.

Acting upon requests by entities in Georgia to obtain municipal and industrial water supply from Corps reservoirs in Northwest Georgia (Lake Lanier, Lake Allatoona and Carters Lake) to provide the projected 2010 needs of the Metro-Atlanta area and two other Georgia communities, the Corps, in October 1989, issued draft water supply reallocation reports proposing the reallocation of storage from hydropower to water supply in these lakes. The draft reallocation reports contained - along with demand and economic analyses - documentation of environmental evaluations conducted under the provisions of the National Environmental Policy Act (NEPA). Shortly after public notification of the proposed reallocations by the Corps, the State of Georgia - in an unrelated action - applied to the Corps (Savannah District) for a permit to construct a water supply reservoir, the West Georgia Regional Reservoir, on the Tallapoosa River, approximately five miles upstream of the Alabama-Georgia state line.

Serious concerns and objections were expressed by stakeholders and the general public in meetings throughout the basins regarding the proposed actions. The prevailing concern was that Atlanta would incrementally increase water withdrawals from the basins in years to come resulting in significant adverse downstream environmental and economic impacts. Many charged that historical water resources decisions in the basins had been made piecemeal and that cumulative impacts of all potential water resources actions should be evaluated and determined before further decisions were made. The news media sensationalized the "Water War" and in many instances reported grossly inaccurate information pertaining to the magnitude and effects of the proposed actions. The conflict also became a significant issue in the Alabama Gubernatorial election of 1990 and in some Congressional races. See Figure 2. This thing had become quite a serious matter and many felt it was high time some steps were taken to see what could be done about it.

The Lawsuit. On June 28, 1990, the State of Alabama filed litigation in the Federal District Court for Northern Alabama challenging the adequacy of the Corps NEPA documentation which addressed the proposed reallocations. Shortly after the litigation was filed by Alabama, representatives of Alabama and Georgia began discussions seeking to resolve the conflicts between the two states. Soon thereafter, the Corps and the State of Florida joined the discussions.

There was general agreement among the parties that litigation was the least desirable option for resolving the water resource conflicts. The State of Alabama requested the Court to defer the litigation while settlement negotiations were pursued. The Court granted this request.

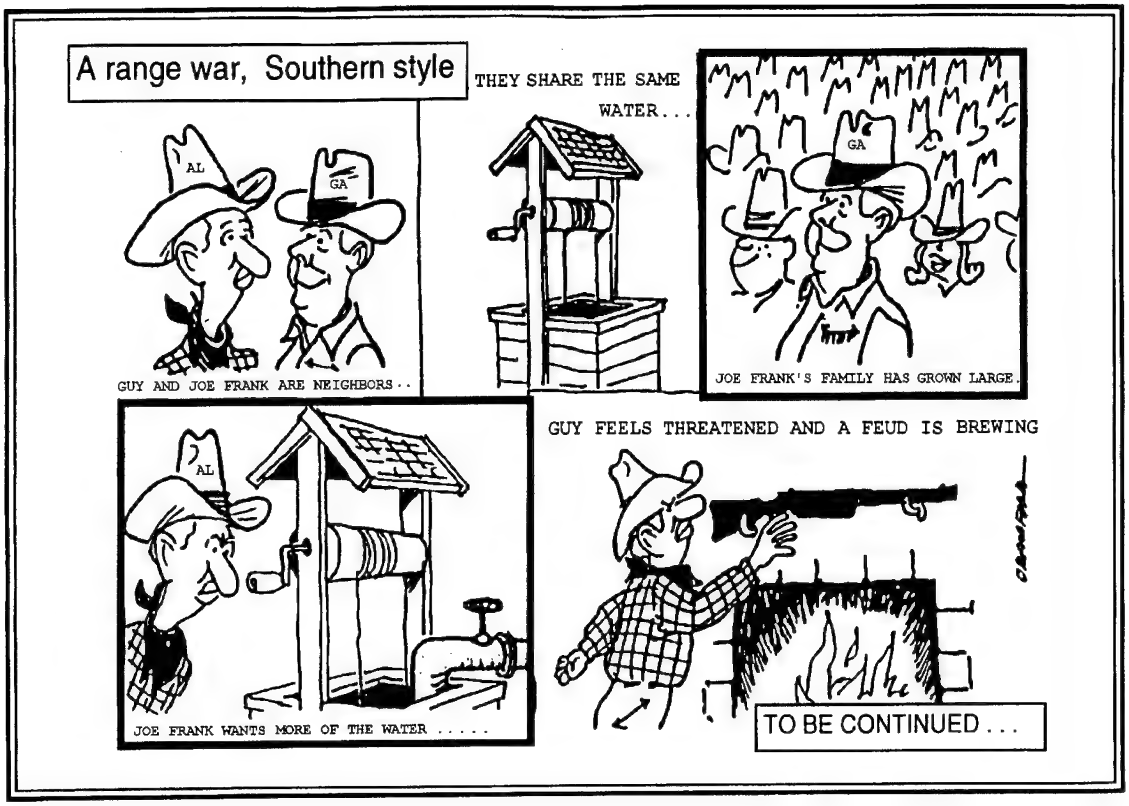

Figure 2

<u>The Memorandum of Agreement</u>. The Governors of the States of Alabama, Florida and Georgia and the Assistant Secretary of Army (Civil Works) signed the MOA on January 3, 1992 and committed to work together as equal partners on a Comprehensive Study to seek resolution of water resources issues. The MOA contained the following provisions:

1) The parties committed to a process for cooperative management and development of regional water resources.

2) The parties agreed to participate in the Comprehensive Study as equal partners.

3) The States committed to contribute direct and indirect monetary resources to the study process.

4) The parties agreed to exert their best efforts to complete the Comprehensive Study, or a substantial part thereof, within three years.

5) The study report will include as a minimum:

   a) A conceptual plan for water resource management of all water resources including management of Federal and non-Federal impoundments in both basins.

b) An assessment of the existing and future water resource needs, including needs of human, economic, natural and other systems.

c) An assessment of the extent of water resources available within each basin to service such needs.

d) An appropriate mechanism or mechanisms to implement the findings or recommendations of the comprehensive study.

6) A "live and let live" concept was adopted for water utilization while the study is underway. This concept includes a notification procedure for proposed new or increased withdrawals. The Corps agreed to operate the Federal reservoirs in the two basins to maximize the water resource benefits of the basins as a whole.

7) The parties committed to establish a system for facilitating the resolution of any future disputes regarding the Comprehensive Study. The system shall include non-binding mediation for issues which cannot be resolved through negotiations.

8) The Court would be petitioned to place the litigation initiated by the State of Alabama against the Corps to an inactive docket pending completion of the Comprehensive Study. (The Court subsequently granted this request.)[3]

THE ACT/ACF COMPREHENSIVE STUDY

General. The U.S. Congress provided initial funding in 1990 for the Corps to conduct a comprehensive water resources study in the ACT and ACF basins. The following Congressional language accompanied the Fiscal Year 1991 appropriation of funds for the Comprehensive Study, *"This study will evaluate the long-term water resources availability and needs within the two river basins. When complete, this study will provide the Governors of the three States with the information they need to develop a mutually agreeable plan for the allocation of available water in the basins."* The Comprehensive Study provides an opportunity to address the availability, quality and projected long-term water resources demands as well as the cumulative effects of various water management alternatives in the two basins.

Goal and Objectives. The goal of the Comprehensive Study is to develop relevant technical information, water resources strategies and plans, and to recommend a formal coordination mechanism for the long term management and use of the water resources to meet the environmental, public health and economic needs of the basins. The objectives of the Comprehensive Study are:

1) Conduct a comprehensive assessment of present and future water demands and the historic and present availability of water resources in both basins.

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[3] *Memorandum of Agreement*, January 3, 1992.

2) Develop implementable strategies for the planning period (through the year 2050) for the basins to guide water management decisions for a full range of hydrologic conditions.

3) Recommend a permanent coordination mechanism for the implementation of water resources management strategies.[4]

Study Management and Coordination Structure. A formal study management organization has been adopted by the study partners for the Comprehensive Study. The study management organization is shown in Figure 3. The management and coordination of the Comprehensive Study is the responsibility of the Executive Coordination Committee and the Technical Coordination Group. The individuals who serve in these capacities are formally appointed and have been delegated certain responsibilities and authorities. Descriptions of each component of the study management organization follow.

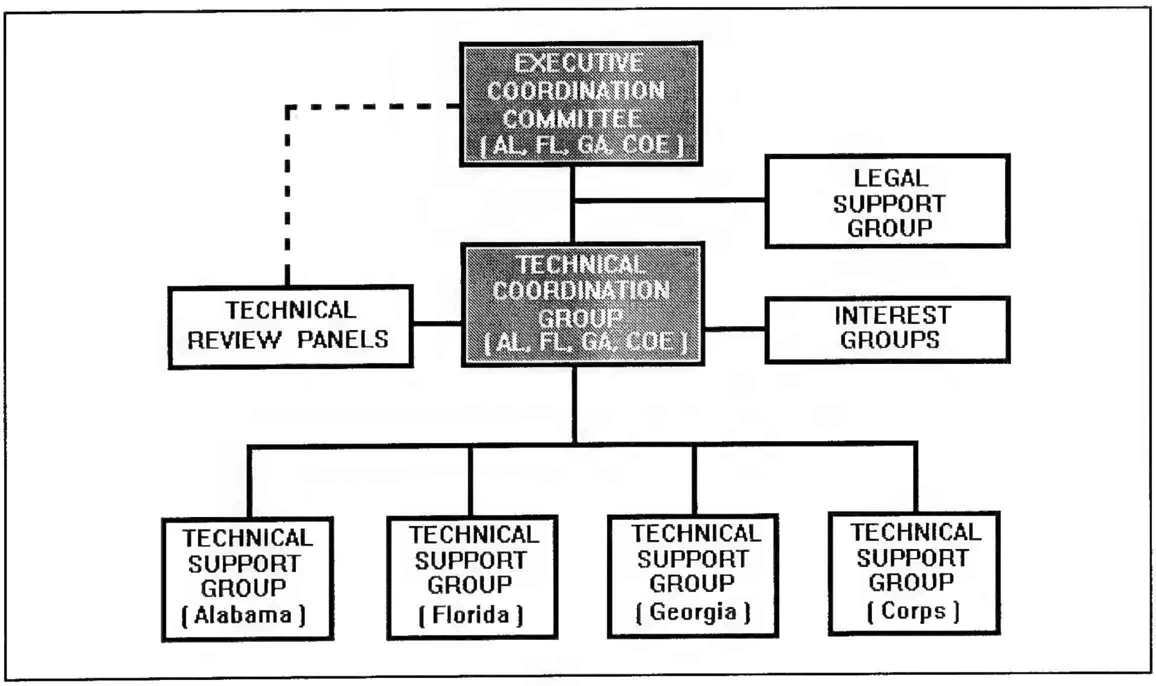

Figure 3

1) Executive Coordination Committee (ECC). The function of the ECC is to provide executive oversight for the Comprehensive Study. It is comprised of four members; one member from each state and the Corps. The state members are formally appointed by the respective Governors and the Mobile District Engineer represents the Corps. The primary responsibilities of the ECC are:

[4] *Volume I, Plan of Study, Comprehensive Study, Alabama-Coosa-Tallapoosa and Apalachicola-Chattahoochee-Flint River Basins*, Technical Coordination Group, January 1992.

a) Establish and approve all policy matters related to the study.

b) Adopt annual and total study budgets prepared by the Technical Coordination Group.

c) Approve all contracts or other agreements for the performance of work under the study.

d) Adopt a Conflict Resolution Plan and provide for issue resolution on matters not resolved at other levels of the study.

e) Report annually to Congress and the Governors.

f) Negotiate agreements between or among the states and the Corps.

2) Technical Coordination Group (TCG). The principal responsibility of the TCG is to provide technical, budget and schedule management for the study. The TCG also has four members, each of which is formally appointed by the respective ECC members. The responsibilities of the TCG are to:

a) Report quarterly to the ECC on the progress of the Comprehensive Study.

b) Provide technical direction for the Comprehensive Study by:

- Establishing the priority, budget and schedule for each study element;
- Determining the types of analyses to be performed, the methodologies to be employed, and the geographic areas to be analyzed;
- Developing and implementing technical scopes of work for the study elements;
- Developing, for ECC approval, annual and total study budgets;
- Recommending, for ECC approval, the entities to perform and the compensation for any work to be done, and;
- Reviewing and coordinating technical products.

c) Coordinate the Comprehensive Study process.

d) Prepare a Conflict Resolution Plan to resolve issues related to the Comprehensive Study.

e) Design and implement a public involvement program.

3) Legal Support Group. The purpose of the Legal Support Group is to provide legal expertise, as required, to the study effort. Responsibilities of the Legal Support Group include recommending necessary studies to the TCG, reviewing information and recommendations produced by the study, and developing agreements among the study partners.

4) Technical Review Panels. Technical Review Panels (TRP) are selected, as needed, by the TCG and approved by the ECC to provide peer review of technical analyses and products produced by the study. Recommendations made by a TRP are furnished to the TCG or the ECC, as appropriate, for approval.

5) Technical Support Groups. Technical Support Groups are selected and formed by each of the study partners but do not have the formality of membership as certain other components of the study management organization. Members of the Technical Support Groups collectively represent a wide range of interests and stakeholders within the basins and are typically affiliated with Federal, state or local agencies and public and private organizations with technical expertise related to specific elements of the Comprehensive Study. Participation in a Technical Support Group affords the opportunity to join actively in the Comprehensive Study process and may include reviewing technical scopes of work and products, recommending studies or methodologies, furnishing technical data, and performing technical analyses.

6) Interest Groups. Interest groups are shown in the study management structure to indicate that other groups or individuals, not involved through other facets of the study, with water resources concerns or interests have an avenue to participate in the Comprehensive Study.[5]

Elements of the Comprehensive Study. The Comprehensive Study is divided into two major components: technical studies and the coordination mechanism element. The technical studies are further divided into water availability elements, water demand elements and the basinwide management element. All elements of the study are underway. Each element of the study is described as follows.

1) Water Availability Elements. The water availability elements consist of both surface water and groundwater elements. The purpose of the water availability elements is to quantify the amount of surface water and groundwater that is available within the basins. The surface water availability element is utilizing the HEC-5 model while the groundwater availability element, due to cost limitations, is utilizing a hydrograph separation technique for most areas. One groundwater numerical model is being used in the southwest Georgia geographic area.

[5] *Ibid.*

2) Water Demand Elements. The objective of the water demand elements is to determine the water needs - both quantity and quality - for the various purposes and uses throughout the basins to the year 2050. The water needs for Agriculture, Apalachicola River & Bay, Environment, Municipal & Industrial, Navigation, Power Resources and Recreation within the basins are determined by the demand elements. Generally included in the category of water demand elements are two water quality modeling efforts. A one-dimensional water quality model, HEC-5Q, is being developed to provide an assessment of basinwide water quality effects from alternative water management practices. The CE-QUAL-W2 water quality model, a two-dimensional model, will be used for three selected reservoirs within the basins which have unique water quality characteristics.

3) Basinwide Management Element. The Basinwide Management element of the Comprehensive Study involves a process for the identification of water management alternatives and the integration of information and models developed in each of the other study elements for alternatives evaluations. The model selected to integrate much of the information is the STELLA II model, a shared vision model developed by High Performance Systems, Inc. It is envisioned that the STELLA II model will be used as an alternatives screening tool while the specialized models - HEC-5, PROSYM power dispatch model, HEC-5Q, CE-QUAL-W2, and others - will be used to provide more detailed information in the refinement of promising water management alternatives.

4) Coordination Mechanism Element. The objective of the Coordination Mechanism study element is to investigate the need for an appropriate mechanism(s) to manage each basin's waters and, if needed, to recommend a coordination mechanism(s) for that purpose. The two major components of the Coordination Mechanism element are: 1) to provide pertinent information to policy makers and stakeholders concerning existing coordination mechanisms existing within the basins and elsewhere, and 2) to conduct a facilitated decision process among the study partners to reach agreement on the coordination mechanism(s) which may be implemented.

CONCLUSION

The Comprehensive Study of the ACT and ACF River Basins has, from the development of the Plan of Study in 1991, been conducted on a full partnership consensus basis among the States of Alabama, Florida, Georgia and the U. S. Army Corps of Engineers. Due to the difficulty in conducting a consensus process coupled with the conflicts existing at the initiation of the study, many gave little hope of a successful completion to the Comprehensive Study. Although many challenges still remain as we work toward completion, the partnership is still functioning and all parties remain committed to the study process. The partners define success as: 1) development of agreed upon analytical tools and models, 2) the recommendation of a permanent Coordination Mechanism(s), 3) agreement on a plan for the management of the water resources of the basins, and 4) agreement on a plan for follow-on actions. The scheduled completion date for the study is September 1996.

USING SHARED VISION MODELS IN THE ACT-ACF STUDY

by

William J. Werick, Richard N. Palmer, Joe Trungale, Alan Hamlet, and William Rowden[1]

OVERVIEW

This paper describes an ongoing process to develop simulation models that constitute a shared vision of how the management of Alabama-Coosa-Tallapoosa, Apalachicola-Chattahoochee-Flint River basins does and could affect the people who use those waters. The University of Washington and the Corps' Institute for Water Resources are leading the development of the models for a partnership consisting of the Corps' Mobile district and the states of Alabama, Florida, and Georgia. The partners agreed in 1992 to jointly conduct a Comprehensive Study of these two river basins. With fewer than nine months left in the study, there are many reasons to fear that the Comprehensive Study's potential to manage longstanding interstate conflicts may not be realized. However, even if the partners do not achieve the stated goals of the Comprehensive Study, the Study has created the necessary knowledge to begin development of such a plan. The question now is whether this hard won knowledge will dissipate when study funding runs out in October 1996.

HISTORY OF THE CONFLICT

There have been conflicts over the management of these basins at least since an 1859 court decision (*Alabama v. Georgia)* that the west bank, rather than the center of the Chattahoochee was the eastern border of the State of Alabama (Erhardt, 1992). More recently, there was controversy between Florida and upstream interests over navigation improvements on the Apalachicola River throughout the 1970's and early 1980's. In 1983, in order to avoid litigation, the three states and the Mobile district of the Corps of Engineers reached an agreement that allowed the removal of rock shoals from the navigation channel with the following conditions: the ACF system would be managed in a more holistic manner; basin-wide studies would be conducted; drought management and navigation maintenance plans would be developed, and an "Interim Coordinating Committee" would be established to manage implementation of these agreements (Leitman, 1992). The shoals were removed and progress was made on the various studies, including the navigation maintenance plan. However, as years passed, the Interim Coordinating Committee (later called the Interstate Coordinating Committee) drifted into inactivity.

[1] William J. Werick, P.E. Policy Analyst, USACE Institute for Water Resources, Alexandria VA. Richard N. Palmer, Ph.D., P.E., Professor of Civil Engineering, University of Washington, Seattle. Joseph Trungale, Alan Hamlet, and William Rowden: Graduate Research Assistants in the Department of Civil Engineering, University of Washington

Droughts in the 1980's triggered another interstate dispute that is still being played out. The Mobile District developed an "Interim Drought Management Plan" in April 1985 for the Apalachicola-Chattahoochee-Flint Basin. This plan evolved as part of a Memorandum of Agreement between the states of Alabama, Florida, Georgia, and Mobile. The plan addressed a variety of issues such as water use and availability problems, existing drought management efforts, and institutional constraints. It also identified the need for a Drought Management Committee (DMC), consisting of USACE officials and representatives from each of the states involved, to coordinate and develop management responses by the respective agencies. The plan was used during a severe drought in 1986. A decision was made to reduce releases to generate hydroelectric power and to serve downstream navigational needs from Lake Lanier so as to improve service of the water supply needs of Atlanta and its suburbs. This restriction continued until the spring of 1987 when conditions improved temporarily. When drought returned in 1987-88, the Mobile district, in concert with the Drought Management Committee, again restricted water releases from Lake Lanier for both hydroelectric generation and for navigation (Riebsame, 1990).

In 1989, Mobile recommended reallocation of part of the storage of Lake Lanier from hydropower to water supply; and at about the same time proposals were made for a water supply reservoir on the Tallapoosa river in Georgia, upstream of the Alabama State line. These developments changed the nature of the water controversy. Instead of concern over localized effects of navigation improvements, the downstream states began to visualize much broader environmental damage and limitation of growth caused by reductions in river flow due to consumptive use of water. Consequently, Alabama filed suit against the Corps Engineers in June 1990, challenging the Lanier reallocation.

Alabama's lawsuit challenged the Corps' proposal on two counts. First, the proposed allocation was described as a violation of common law rights since it allegedly provided upstream interests with water at the expense of current and future downstream users. Secondly, the suit alleged that the Corps did not fully comply with the requirements of the National Environmental Policy Act, since the downstream environmental impacts of the proposed reallocation were not fully addressed (Alabama vs the United States, 1990). The states of Florida and Georgia formally filed petitions to intervene in August and September of 1990, respectively.

The three states and the Corps of Engineers eventually decided to seek a negotiated solution to the controversy, establishing the ongoing Comprehensive Study. It was agreed that the new comprehensive planning effort would be jointly managed by the four parties. That decision was formalized by a Memorandum of Agreement, January 3, 1992, signed by the Governors of the three states and the Assistant Secretary of the Army. This agreement established a three-year period, during which existing water uses would not be curtailed, and no new allocations or major diversions would be approved. Litigation was placed in an inactive docket pending completion of the studies; the suit can be rejoined at any time after the expiration of the Memorandum of Agreement (MOA, 1992). The Memorandum of Agreement was subsequently extended to September, 1996.

THE MANAGEMENT STRUCTURE OF THE STUDY

All major decisions during the Comprehensive Study require the consent of all four partners. There is a dispute resolution process designed into the consensus requirement, but it has rarely been used. There are both advantages and disadvantages to this study management structure. The structure addresses two concerns raised in every call for integrated or watershed management: the openness of the study process, and the direct involvement of all the major decision makers in the conduct of the study. This addressed one of the primary charges in Alabama's suit (Alabama v. the United States, 1990), that the Corps had not followed the collaborative requirements of the National Environmental Policy Act. The main disadvantage is that an enterprise with four bosses may be an enterprise with no boss, since no *one* bears the ultimate responsibility for producing results. A less obvious flaw is that the partnership does not have the management infrastructure found in any but the smallest enterprises - rules for hiring, firing, promoting, and managing processes. How does the partnership encourage the good behavior and discourage the poor behavior of team members? What happens when there is a conflict between quality and timeliness? What happens when there is a personality conflict that gets in the way of the work? Whereas each agency has guidance for supervisors, performance reviews and awards, and the orderly delegation of authority, the partners as a group have no rules except those they impose as the conduct the study.

The requirement for consensus slows progress but also encourages the growth of more comprehensive water resources management skills throughout the basin. Decisions that would be made quickly by an expert consultant may take months in a consensus study process, and much of that delay is because decision makers are obliged to truly understand the consequences of the decision. This can be true within a field (what method should be used to route flows?), but it is even more problematic across fields (is the resultant differences in flow significant given the errors and uncertainties in demand estimates?). The need to debate technical choices has probably contributed to a rivalry among modeling groups which created an initial suspicion of the shared vision process. For example, one university professor in the basin actively tried to convince stakeholders to abandon the shared vision models and use linear programming models. There was also a rivalry between HEC5 and STELLA II ®, and a considerable amount of time was spent explaining the different roles and possibilities for each modeling platform. However, the conflict has improved the general understanding of how specific models can best be used, and the challenges to STELLA II ® have generally produced excellent criticisms that have improved the shared vision models and the confidence stakeholders have in them.

THE WORK ELEMENTS OF THE ACT-ACF COMPREHENSIVE STUDY

There are three primary goals for the ACT-ACF Comprehensive Study and these define the basic work elements: to assess future demands through the year 2050, and compare that to water availability; to develop a "conceptual basinwide management plan" for each basin; and to create a better mechanism for the coordination of future water management decisions. (MOA, 1992).

Studies are being conducted to determine:

- future population and employment in each basin
- the availability of surface and groundwater
- current water quality in the basins (two modeling efforts)
- estimate demands and (in some cases) the impacts of shortfalls for: (a) municipal and industrial water use; (b) navigation; (c) water based recreation; (d) agriculture; and (e) electrical power. Environmental water needs studies are being conducted on (a) riverine and estuarine wetlands; (b) reservoir fisheries; (c) riverine habitat; and (d) protected species.

A companion study of the Apalachicola River and Bay, conducted by the Northwest Florida Water Management District, is expected to be finished in October 1997, with preliminary results used in the Comprehensive Study. The basinwide assessment and evaluation of alternatives is dependent on information from these studies. The basinwide work may in turn influence a study of potential coordination mechanisms. The water quality studies do not include forecasts of future loadings, and so water quality is not part of the basinwide assessment or evaluation. The partners have acknowledged that there will be substantial investments in treatment facilities. These water quality investments could have a direct effect on water supply issues, because of the potential for reducing land application of wastewater, which would increase returns from water used by municipalities. The shared vision models do, however, include variable instream water quality flow targets, and they measure the instream flow target reliability (the percent of total months the target is met) and vulnerability (the average failure, in *cfs*, to meet the target).

These studies were designed collaboratively by the partners with the attendant advantages and disadvantages of group design. The scope of work for the basinwide element was not finalized until after all the demand studies were underway, and each element reflects a unique mix of interest and expertise among its authors and monitors. As a result, there are some non-critical inconsistencies, and a small amount of follow-on work was necessary before the studies could be brought together under the basinwide umbrella. A brief description of the intended products from the demand studies is shown in **Table 1**.

Mobile District is conducting the surface water study element with assistance, direction, and quality control provided by the Corps' Hydrologic Engineering Center. This element will produce an HEC5 model of each basin and will develop unimpaired historic flow sets for the assessment and evaluation of basinwide management plans. The period of record is from January 1939 to December 1993. HEC5 models will use daily flows, but the basinwide analysis will use monthly flows. Some of the demand studies, particularly environmental, power, and navigation, require HEC5 outputs. A conceptual link between the two models was recommended jointly by HEC5 and STELLA II ® modelers (Werick, April 1995), but there are many questions about the ultimate connections between the models. Almost all of this uncertainty is beyond the power of the modelers to change at this point, since there are no approved data, and a step by step process for formulating and evaluating alternatives has not been approved.

Table 1
Summary of Demand Studies in the ACT-ACF Comprehensive Study

Demand Element/ Contractor	Alternatives designed within the element	What does the study forecast or estimate?
Agriculture/ Natural Resources Conservation Service	Conservation	Forecasts consumption for 5 product categories (livestock, crops and orchards, aquaculture, nurseries, and turf farms) for three economic assumptions (low, medium, and high), each with and without water conservation. Source of water identified as specific river or reservoir, groundwater, and pond fed by streams or local runoff). Estimates revenues lost to farmers if water is not available.
Environment/ U.S. F.W.S. and WES	None	Estimates suitability of various water regimes (for example monthly flow patterns). Estimates some direct effects (e.g. acres of types of habitat).
M&I/ IWR (PMCL)	Aggressive basinwide conservation	Forecasts monthly demands under 3 scenarios (baseline, with future effects of existing conservation programs, with aggressive basinwide conservation). No economic impacts.
Navigation/ Mobile, IWR	Several (see right).	Estimates flow needs under a variety of weirs, dikes, channel reach and depth. Forecasts demand for shipping and NED changes related to channel availability.
Power North Pacific Division	None	One forecast of demand for power and cooling water. Changes in dependable capacity, NED benefits estimated.
Recreation/ WES	No	Visitation/elevation curves. Estimates changes in NED benefits, direct revenues.

The groundwater study was subdivided into eight studies according to geographic subareas. A numeric model was developed for one area, the Lower Flint at the Georgia-Florida boundary. Most of the groundwater that is used in these basins is used in that area, and pumping affects both baseflows into the Flint during droughts and cross-state flows within the aquifer. Both effects are quantified by the numeric model, and will be included in the basinwide analysis. The Comprehensive Study did not develop any yield information for any groundwater system, nor were baseflow-pumping relationships developed in any of the other areas. In general, it is thought that where groundwater is available, it is plentiful. Georgia has recently estimated relationships for the whole study area between pumping and baseflow and has assessed the capability of aquifers throughout the basin to supply future pumpage. The Georgia paper may, in some variation, be accepted by the partners and used in the shared vision models.

INTRODUCTION OF THE SHARED VISION CONCEPT INTO THE ACT-ACF STUDY

Shared vision models are computer simulation models of water systems - including environmental and economic impacts - built, reviewed, and tested collaboratively with stakeholders. The shared vision model concept is an evolutionary form of well founded water resources methods, especially multi-objective water management as espoused by the Harvard Water Program (Maas, 1962), and the use of easy to understand simulation models in the formulation and negotiation of water supply alternatives for the Washington, D.C. area in 1980 (Steiner, 1993). The approach was updated during the National Drought Study using a software package called STELLA II ®. It was used experimentally in five case studies (Babcock 1993, Bart 1993, Lochen 1993, Stiles 1993, Nvule 1993).

A computer model that achieves a shared vision can be used as a "single text negotiating document" (a summary of facts and assumptions to which all disputants agree). A single text negotiating document in the form of a STELLA II ® simulation model allows the disputants to quickly determine how they would fare under a variety of management plans and exogenous future events because the model dynamically links effects and the interdependencies among those facts and assumptions.

In the Spring of 1993, after many months of unsuccessful attempts to develop a basinwide process, the partners asked the Corps' Institute for Water Resources to apply the shared vision planning method to their requirements for a basinwide study. IWR agreed to become involved in the interest of helping the partners and testing the shared vision approach in a large, long term planning study. The University of Washington is leading the modeling work for IWR, as it did during the National Drought Study. Although the method is a form of planning, many of the Corps participants in the National Drought Study were water control engineers. This is a reflection of the shift in the Corps budget and mission from project development to project operations and maintenance. A question raised, but not answered here is how the Corps will train and support its water control staff to respond to water conflicts using what are essentially multipurpose, multiobjective tradeoff analyses.

THE BASINWIDE STUDY PROCESS

The basinwide management process is divided into three phases: mock products, performance trials, and the effects stage. The "mock" stage was created in recognition of the difficulty of developing reports and models agreeable to four equal and litigious partners. The mock models provided a tangible example of an unfamiliar product. Like a model house, the mock models helped state staff and stakeholders to imagine what they would like in their own shared vision models. Comments on the mock models were solicited from stakeholders in the first of three meeting of about 80 key stakeholders known collectively as the Basinwide Management Task Force.

The "performance trials" concept was proposed by IWR in March 1994 as a first attempt to build a shared vision model for each basin capable of assessing water needs and evaluating alternatives. Alabama Power, a key stakeholder with skilled modelers, recommended that a "Water Balance Model" be prepared, reviewed and endorsed as a first step in the Performance Trials and that suggestion was endorsed by the partners. The Water Balance Model incorporates the written reservoir operating rules from the Corps Water Control Plans and the power companies licensing agreements.

The final phase of the study, which is supposed to include the formulation and evaluation of alternatives, has actually started as well. The overlap of the second and third phases is necessary because there so little time left in the study to complete the last phase.

DISTINGUISHING CHARACTERISTICS OF SHARED VISION MODELS

There are some basic differences between the ACT-ACF shared vision models and the models traditionally used in water resources studies.

1. The models are expressly designed to be used in negotiated decision making. This is manifest in the amount of time the modeling team spends determining and articulating what is important to decision makers. Of course, this is helped by the fact that the modeling team includes people close to the decision makers as well as members who are skilled modelers.

2. Stakeholders understand and trust the models more because they are more involved in their development. In this study, the modeling effort is guided by the Basinwide Management Working Group, composed of IWR, the University of Washington, and two representatives from each of the four partners. Stakeholders have involved themselves at various levels. A few of the key stakeholders, like the Alabama and Georgia Power Companies, are working closely with the Basinwide Management Working Group and have been intimately involved in certain aspects of the modeling process. The Atlanta Regional Commission has asked a consultant engineer to criticize the models and work with us to make sure their interests are accurately represented. The Basinwide Management Task Force, consisting of about 80 key stakeholders, has met twice in workshops to advise and monitor the model building effort. The Florida Task Force members meet regularly with Florida to discuss the models. Some Georgia members,

who form an advisory group for the Governor, track the models almost as closely. There is no similar process for Alabama stakeholders, but they are active participants in the Basinwide Task Force Workshops.

3. The models dynamically combine a variety of results from other computer models and forecasting studies so that the effects of different combinations of results from each of those studies can be calculated. **Table 2** lists the demand study results that can be mixed in combinations for any alternative and any demand forecast year.

4. The models use a commercially available systems simulation modeling environment, rather than a dedicated software developed by water resources specialists.

SOFTWARE

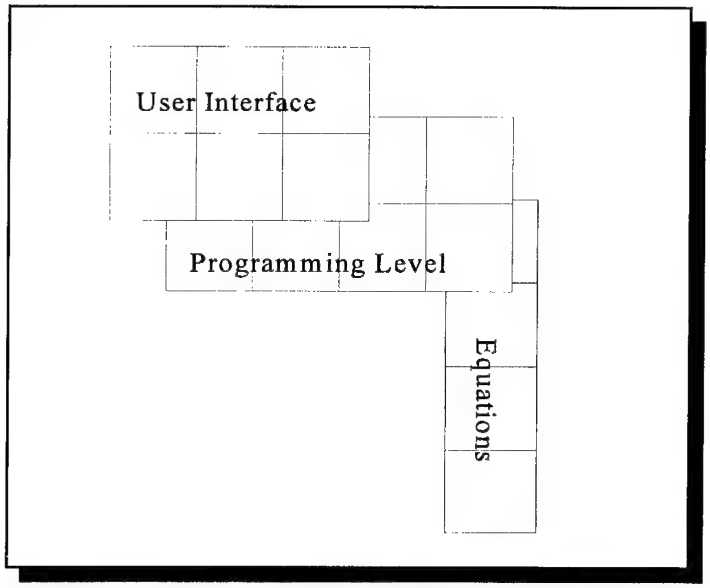

Figure 1. Three Levels in a STELLA II ® Model

There are other software products such as Powersim ® that could be used to build shared vision models, but STELLA II ® was the original choice because during the time of the National Drought Study it provided the best combination of power and user friendliness (Keyes, 1993). STELLA II ® is now available for Windows and Macintosh operating systems, and in a basic and "authoring" version. The ACT and ACF models use the Windows Authoring STELLA II ®. The Authoring version provides additional control and output devices on the user interface level. Programming is done at the middle of the three levels (**Figure 1**) using four icons: *stocks, flows, convertors, and connectors.* The value of a stock in time t is the value of that stock at time $t-1$ plus the product of all inflow rates times dt minus the product of all outflow rates times dt. The user must specify the initial value of the stock. Flows are user defined rates. Connectors are used to link icon x to icon y such that if the connector arrow points from x to y, then y is a function of x. (Connectors cannot be drawn to stocks since they are always defined as a function of their past values, inflows, and outflows.) Convertors are general purpose icons which can be defined as constants, equations, or graphs. There are currently 69 built-in statistical and logical operators such as IF, THEN, INTEGER, SIN, ABSOLUTE VALUE, DELAY, RANDOM, etc. that can be used to define flows and convertors. Almost anything shown on the screen (except some programming/dialogue boxes) can be printed; all three levels can be viewed on the screen as they would be printed on a variety of paper sizes. STELLA II ® software allows the user creative latitude in programming and designing the appearance of the models.

Table 2
Demand Study Results To Be Included in the ACT-ACF Shared Vision Models

<table>
<tr><th colspan="7">Selectable Options from Demand Studies for Each Forecast Year (1995, 2000, 2010, 2020, 2050). Any one column from all rows must be used.</th></tr>
<tr><td rowspan="2">Agriculture Use</td><td>Low</td><td>Medium</td><td>High</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="3">without conservation</td><td colspan="3">with conservation</td></tr>
<tr><td>M&I</td><td colspan="2">Base forecast</td><td colspan="2">Forecast with effects of current conservation measures</td><td colspan="2">Forecast with effects of aggressive, basinwide conservation</td></tr>
<tr><td>Power</td><td colspan="6">One economic (demand load curve) and one thermal cooling water demand per forecast year</td></tr>
<tr><td>Navigation Economic Forecast</td><td colspan="2">Low</td><td colspan="2">Medium</td><td colspan="2">High</td></tr>
<tr><td>Navigation - project extensions</td><td colspan="3">Make the Coosa navigable from Montgomery to Gadsden.</td><td colspan="3">Make the Coosa navigable from Gadsden to Rome</td></tr>
<tr><td>Navigation</td><td colspan="6">Nine structural alternatives: ACF: (1) Chipola cutoff weir, dike fields, and 9,300 cfs target flows. (2) Chipola cutoff weir, dike fields, and 11,000 cfs target flows. (3) 9,300 cfs target flows and dike fields (no Chipola cutoff). (4) 11,000 cfs target flows and dike fields (no Chipola cutoff). (5) 13,000 cfs target flow and dike fields (no Chipola cutoff). (6) ACT: 5,000 cfs target flow and combination additional dredging and dike fields necessary to preserve a nine foot channel year round. (7) 6,600 cfs target flow and combination additional dredging and dike fields necessary to preserve a nine foot channel year round. (8) 7,500 cfs target flow and combination additional dredging and dike fields necessary to preserve a nine foot channel year round. (9) 9,500 cfs target flow and combination additional dredging and dike fields necessary to preserve a nine foot channel year round</td></tr>
<tr><td>Environment</td><td colspan="6">The FWS and WES will provide utility functions that relate flow patterns to physical characteristics (e.g., acres of wetlands) and indices (for example, modified Riverine Community Habitat Assessment and Restoration Concept).</td></tr>
</table>

THE PERFORMANCE TRIAL MODELS

The current version of the shared vision models use only preliminary data, including unapproved unregulated flows (later *unimpaired* flows will eliminate the effect of historic consumption), and unapproved 1990, 2010, and 2050 demands for agricultural, municipal and industrial, and thermal cooling consumption. Given those conditions, the results from the "performance trial" models must also be viewed as very preliminary. Nonetheless, these models suggest the sort of dynamic analysis of which the final models will be capable.

The model also allows the selection of the current water control plan, a recreation plan that reduces releases to keep lake levels higher, a navigation plan that gives releases higher priority, a power plan that allows the hours of peak generation to vary, an instream flow plan that allows the variation of instream flow targets, and a consumptive use plan that makes that the highest priority even as demands increase through 2050.

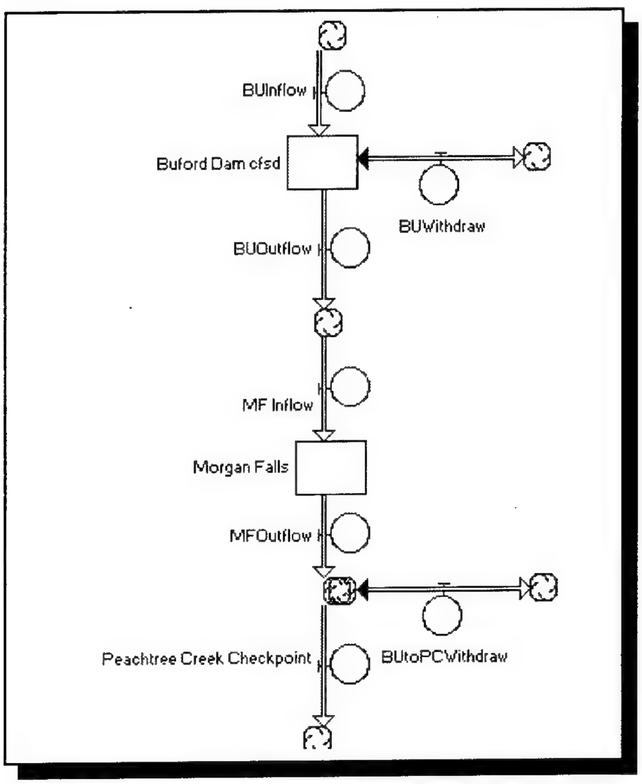

Figure 2. Part of the ACF System Diagram

Water Control Plan. The models used for the Performance Trials allow limited variations on the written operating rules for Corps and power company reservoirs. When the Performance Trial Slider bar is set to "0" (see **Figure 4**) the written rules of the Corps water control plan and the power companies' licensing agreements govern reservoir releases. Mobile district operations branch and power company modelers worked with the University of Washington to make sure the logic and data in the models accurately represented those rules. Mobile, Georgia Power, and Alabama Power each provided a written endorsement of the so-called "Water Control Plan" models. The power companies qualified their endorsement, explaining that monthly time step models had inherent limitations and that the endorsement of the water control plan version did not mean that future versions of the model that included alternative operating plans were being simultaneously endorsed. A comparison of historic reservoir levels and releases and the model's calculated levels shows good, but not perfect correlation; the most significant deviations are understood and acceptable. For example, the water control plan model does not have an operator's leeway to fill reservoirs above the conservation pool when the risk of flooding is low. The historic reservoir elevations show these surcharges, but the water control plan simulation does not.

The modelers developed five variations on the water control plan (Rowden, 1996):

1. The Consumptive Withdrawals Sensitivity Trial determines the impacts of varying consumptive demands under water control plan rules.

2. The In-Stream Flow Sensitivity Trial determines the impacts of various in-stream flow targets on the ACT and ACF basins.

3. The Hydropower Sensitivity Trial calculates the hydropower release for each reservoir using the number of peak week day generating hours selected by the user. The models then compare these hydropower releases to minimum flow and rule curve requirements, and calculate the monthly energy produced using the final (maximum) release. Only the available water (typically the conservation pool) limits the hydropower releases; unlike the water control plan, there are no limitations on hydropower releases due to zone. (Note that the reservoir zones still determine navigation releases in the ACF.) The number of generating hours set on the slider bar is, in effect, the firm energy requirement. If the system can maintain this release throughout the period of record, the energy generated reflects the dependable capacity.

4. The Navigation Sensitivity Trial attempts to meet navigation target values by releases from reservoirs that are not operated as run-of-river facilities. The navigation targets are at Blountstown in Florida (ACF model), and below Claiborne reservoir in Alabama (ACT model). (This replaces the requirement for a total of 4640 cfs released from Jordan, Bouldin, and Thurlow.) A slider bar sets the desired channel depth (and related target flows) at these locations.

5. The Lake Recreation Sensitivity Trial enhances the reliability of summer reservoir elevations above the recreational impact levels by limiting withdrawals and releases. Since lake recreation is most important during the summer, this trial will operate differently from the Water Control Plan only from May through September. The recreational "cutoff" elevation affects the water available for withdrawal and release. The cutoff elevation is the top of the conservation pool minus a maximum acceptable drawdown set on a slider bar. The model will maintain the cutoff elevation at 100 percent reliability by prohibiting withdrawals or releases when the reservoir elevation is at or below the cutoff. At elevations above the cutoff elevation, the model will limit withdrawals and releases to the available water, defined as the volume of water between the current elevation and the cutoff elevation (plus inflows). Supplemental releases (for navigation targets) will be proportional to this available water as well.

Recreational impact levels are the basis for the default values for the slider bar representing the maximum acceptable drawdown. For reservoirs with more than one recreational impact level, the model uses the lowest level as the default cutoff elevation.

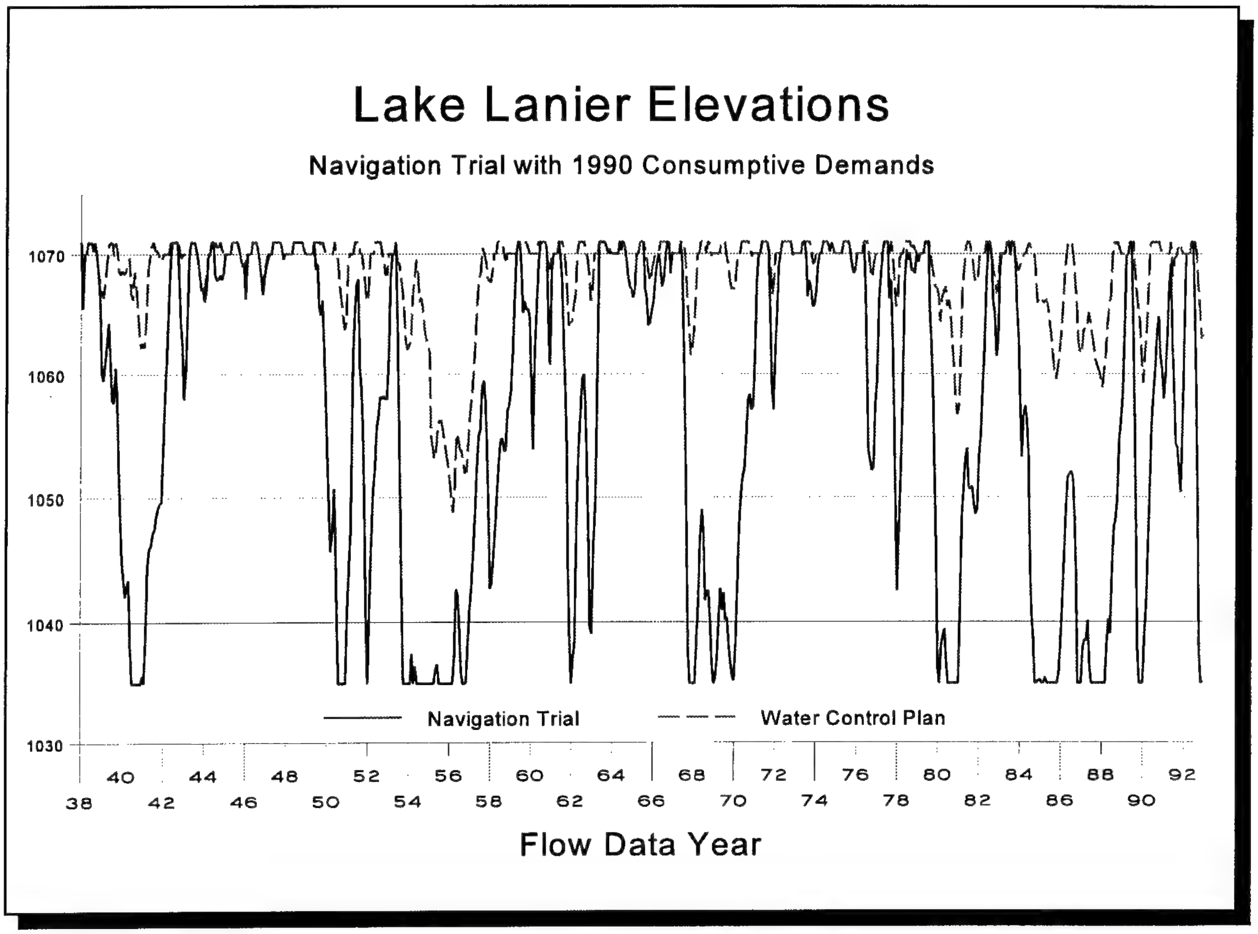

Figure 3. Lanier Elevations Under Two Different Operating Rule Sets

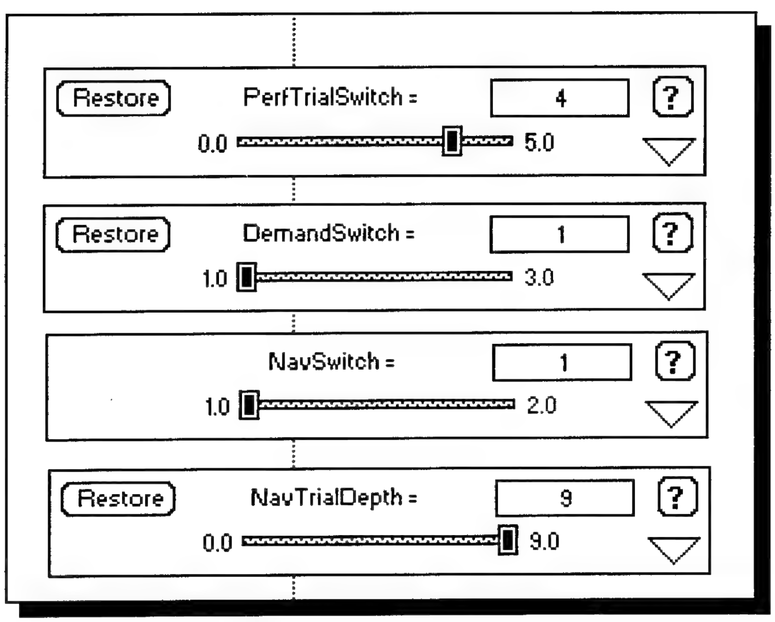

Figure 4. Slider Bars Enable the User to Pick Demands and Operating Rule Sets

THE SECOND BASINWIDE MANAGEMENT TASK FORCE WORKSHOP

> ***Excerpt from the Columbus Ledger-Enquirer***
> ***Ken Edelstein, January 12, 1996***
>
> *"This week's meeting was a sort of coming out party for the partially completed $15 million study. Barge boosters, power company executives and environmentalists were among those who learned to run a computer program that allows them to tinker with different scenarios for sharing water into the middle of the next century."*
>
> *"Overall, stakeholders seemed pleased that they'll finally get a chance to see how such changes as residential water demand could limit hydroelectric power. Punching numbers into the program to change ideal depths of navigation channels could reveal, for example, how lake levels would be altered."*
>
> *One participant admitted however, that the program would be better if it performed just one more task.*
>
> *"Can you make water with this thing?" asked Alabama's Walter Stevenson."*

The models were used in the second Basinwide Management Task Force Workshop in Columbus, Georgia, in January 10-11, 1996. It had been one year since the Task Force had met, and the meeting began with some vigorous discussions of the ultimate purpose and value of the Comprehensive Study and the validity of some of the work, especially regarding agricultural water use in the lower Flint and the subsequent effect on groundwater contributions to streamflow. There were also questions and challenges to the shared vision models regarding the appropriateness of a monthly time step, and the absence of water quality and groundwater information. Many users liked the models but wanted more flexibility in designing their own operating rule sets with slider bars. There were also suggestions on improving variable names and model presentation. General reaction to the workshop and the models was very favorable according to post workshop e-mail from the partners.

NEXT STEPS

The central claim (or conceit) of shared vision planning is its orientation towards results; it is intended to change the way water is managed. In this view, studies which accumulate data, develop models, or increase coordination are worthless unless they lower transactional costs or improve system performance. At this point, the odds are against achieving that kind of success; they are even against the completion of the models. The primary reasons for this are:

the majority of supporting demand data are scheduled for approval in August or September 1996, and these schedules may be optimistic;

the partners rejected a December 1995 IWR proposal for formulation and evaluation of alternatives, but have not produced a counterproposal;

there are no funding plans beyond September 30, 1996, and Senator Sam Nunn of Georgia and Representative Tom Bevill of Alabama, two powerful Congressmen who have supported the study, are retiring and will not be part of the next Congress.

There is also the possibility that planners are being "viewed as rivals for control of policy ..." (Wildavsky, 1973). Not everyone believes that sharing information is good. During the National Drought Study, there was obvious reluctance on the part of two cities to participate. In one case, the city was afraid to reveal its operating policies to the suburban utilities it was supplying. The city had recently found itself with a potential shortfall, and the suburban utilities had agreed to impose restrictions on their customers even they could have demanded full deliveries under the terms of their contracts with the city. Many believed the city was concerned that a shared vision of their management might reveal that they could have avoided the shortfall, leading the suburbs to ask the city to deliver their full supply. In the second case, a city had been involved in a long dispute over a water supply measure, and was afraid that a collaborative drought study would give ammunition to critics who said the city did not need the water. A supplier to this city may also have been leery of exposing its drought vulnerability to major military bases during a time when Congress was evaluating which bases should be closed.

There is still some hope. IWR and UW will work aggressively to accomplish as much as possible by September 30, 1996. The current models are capable of providing many useful insights to those interested in exploring possible future water management in these basins. And the modeling approach has been accepted or even adopted by some early critics; STELLA II ® is now being used by the power companies and (reportedly) by the city of Birmingham. The current models are available on the ACT-ACF Homepage. The address is:

http://atlas.ce.washington.edu/~actacf/

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WATER BALANCE STUDY USING THE WEAP PROGRAM
An Application to the Upper Chattahoochee River Basin, Georgia

by

William K. Johnson[1]

BACKGROUND

Understanding the balance, or imbalance, of all water supplies and demand in a region is a necessary first step toward effective water resource planning and management. Most water resource planning studies whether local, state, or federal address only part of the water picture. They commonly focus on a reservoir, or reservoir system, on a river and reservoir, or on a groundwater aquifer. A comprehensive and integrated picture of all of a region's supply and use, both present and future, is not usually created. The task of developing a water balance, or water budget as it is sometimes called, has been the subject of research at the Hydrologic Engineering Center (HEC) for a number of years (Hayes, et al., 1980). The content, guidelines and computer programs for water balance analysis have been investigated to find effective ways to define and conduct these studies. This paper describes some of the applications of computer program Water Evaluation and Planning System (WEAP) developed by the Stockholm Environment Institute-Boston, Tellus Institute, to model all supplies and demand in a region and to provide information on the balance, or imbalance, of the water resources under a variety of future conditions. The program was initially applied to the upper Chattahoochee River Basin, Georgia by the Hydrologic Engineering Center as a research project to test its capability as a tool in water balance analysis. A number of desirable additions to the program were identified as part of this effort that has made it more suitable for Corps-wide use and these were made through a contract between the Hydrologic Engineering Center and the Tellus Institute.

This paper has three objectives. First, to provide an overview of the application of the program to the upper Chattahoochee River Basin, Georgia. Second, to briefly describe the capability of the WEAP program to account for all supply and demand in a water balance analysis. A more complete description may be found in the HEC report *Accounting for Water Supply and Demand*, 1994. And, third, to describe some recent applications of WEAP to other watersheds.

UPPER CHATTAHOOCHEE RIVER BASIN

The upper Chattahoochee River is the uppermost part of the Apalachicola-Chattahoochee-Flint (A-C-F) River Basin which includes parts of Georgia, Alabama and Florida (Figure 1). Starting in the headwaters of Habersham County in northeastern Georgia, the Chattahoochee River flows southwest past Atlanta until it reaches the border with Alabama at West Point. Here it turns southward and forms the border between Georgia and Alabama down

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to Florida. At Lake Seminole the Chattahoochee is joined by the Flint from the east. The outflow from Lake Seminole at Jim Woodruff Dam on the border between Georgia and Florida becomes the Apalachicola River. The Apalachicola flows southward through northwestern Florida and into the Apalachicola Bay.

The A-C-F is an important water resource system in the Southeastern United States, providing water for 1) municipal uses in the growing Atlanta Metropolitan Area (AMA) and other smaller communities along both the Chattahoochee and Flint Rivers; 2) hydropower at three major dam sites and other locations; 3) navigation in the lower portions of the system; 4) recreational uses throughout; 5) important environmental concerns including fish and wildlife survival, ecology of Apalachicola Bay, and water quality downstream of AMA; and 6) industrial growth expected in southeastern Alabama and southwestern Georgia.

During the 1980's the A-C-F River Basin experienced two of the worst droughts in recent history. Serious conflicts among competing uses for water arose, and severe actions were necessary to manage the scarce resources during this period. This experience pointed to a need to examine the water resources in a comprehensive and integrated way.

The application of WEAP is concerned with the uppermost portion of the A-C-F Basin from the beginning of the Chattahoochee watershed above Lake Sidney Lanier down to approximately 24 km (15 miles) below Atlanta. This portion was selected because it had several features of major importance to the A-C-F Basin, the city of Atlanta, the major metropolitan area of the region; Lake Sidney Lanier, an important multiple-purpose reservoir; and municipal, commercial, industrial and agricultural uses in both urban and rural areas. At the same time the study area is not so large that it cannot be investigated as a research project.

The time and effort of the HEC research investigation concentrated on developing the application and not on primary data collection. Water use and supply data already compiled and available from existing studies and reports were used . Some of the water use data reflects projections and estimates which have been made by water agencies for future water demand. Use of available data and the excellent cooperation of the water agencies in Georgia allowed the application to be developed quickly and easily. For forecasting questions not specifically addressed in the WEAP application, changes and different assumptions can easily be made to the WEAP model.

An inventory of the water supply and demand features modeled in the upper Chattahoochee study are presented in Table 1 and are discussed in detail in the study report *Accounting for Water Supply and Demand* (1994).

PLANNING QUESTIONS THAT WEAP CAN HELP ANSWER

WEAP gives a holistic, integrated picture of the supply and demand system of the study area at any point in time, and under different user-specified sets of conditions (Figure 2). This picture includes supplies available from rivers, creeks, reservoirs, and groundwater and demand needed for water withdrawals, discharges, and instream flow requirements. Unlike traditional river/reservoir simulation models which are limited to the water resources of a river or reservoir,

WEAP creates a picture of all the water resources of the study area and their consumptive and non-consumptive demands. WEAP is rich in technical detail of the water system (Tellus 1995).

WEAP operates on the basic principle of water balance accounting where different sets of conditions, on either the supply side, the demand side, or both can be investigated. For example, the effects of: changing hydrologic conditions and the occurrence of droughts, different future water requirements, changing the location of a river withdrawal point and/or its quantity, raising or lowering a reservoir conservation pool or buffer zone, or increasing instream flow requirements, can be quickly and easily examined in WEAP. The user, through this kind of investigation of the behavior of the total system, begins to develop a good understanding of the impacts of present and proposed actions on different parts of the system. The relationships, tradeoffs and conflicts between different water uses are highlighted and quantified in the WEAP water accounting picture.

In the upper Chattahoochee Basin, there is concern over the impacts of present and future projected levels of water use in the Atlanta Metropolitan Area (AMA) on the river basin resources. The heart of the matter is the need for planning and management under drought conditions. In WEAP, a unified relational database for all water users, operating purposes, and water supply resources can be configured, stored, modified or updated, accessed and "run" at any point to see the water balance situation for the whole system. Alternative scenarios of future supply and demand can be easily evaluated. By operating the system at different use levels and with priority for different purposes, the WEAP user gains greater understanding of the existing system, the points of conflict, problem areas, and develops insights and actual proposals for better planning and management strategies relative to the needs and desires of all water users in the system.

As the Atlanta Metropolitan Area and other water needs grow, withdrawal and discharge permitting decisions will have to be made. WEAP, with its integrated water accounting database structure, can be used for such real-time planning issues as: the examination of existing permit levels against current actual demand-generated use and discharge levels; the evaluation of whether to permit increased withdrawal or discharge levels at existing sites; the evaluation of potential new permit withdrawal points and their appropriate level with respect to other purposes in the system. WEAP can also be used to investigate the relationship between reservoir operation and system demands, water transfers into and out of the study area, possible new structures for storage or flow regulation, re-allocation of reservoir storage, and the effects of municipal and industrial water conservation practices.

Because the WEAP model is very transparent to the user, operates as a simulation model, and is based on relatively simple water balance accounting principles, it can support another important function for the upper Chattahoochee study and for the decision-making process. That role is as a tool for all the different parties involved in watershed management to evaluate and negotiate the options, policies and proposals from a common framework of data, assumptions, and terminology. The model is built upon detailed data familiar to the different water agencies: reservoir and river data from the Corps of Engineers, permit data from the state of Georgia, demand site and demand projections from the Atlanta Regional Commission, and streamflow data from the U. S. Geological Survey. With these data in the WEAP model, the outcomes and

consequences of alternative operations can be verified and easily communicated among the group of players in the decision-making process. This facilitates open and concrete discussions about alternatives and impacts.

SOME FEATURES OF THE WEAP MODEL

Figures 3 and 4 show the demand sites and stream gages for the upper Chattahoochee River Basin. These are the essential elements of the water demand and supply which WEAP models. For each demand site in Figure 3, for example, the city of Atlanta Metropolitan Water System, WEAP can model a number of features. Some of these are illustrated in Figures 5 thru 9. Figures 10 thru 14 illustrate some of the results obtained in the WEAP model. Most tabular results such as those in Figures 10 thru 14 can also be displayed graphically as a pie, line or bar graph. A fuller description of the features of WEAP are illustrated in *Accounting for Supply and Demand* (1994).

OTHER WEAP APPLICATIONS IN WATERSHED PLANNING

Recent applications of WEAP to other watersheds illustrates its diverse capabilities to meet the needs of water resource planners and accommodate their imagination and creativity. It is being used with GIS data and software, in conjunctive use management, for interstate water allocation, to model water rights priorities, and to manage water flow and quality.

San Juan Basin, Mexico. This study was undertaken by Halff Associates, Inc., Fort Worth, Texas, Lynn Lovell, a former Corps engineer, was project manager. The study had three objectives for which WEAP was used: (1) to prepare a supply-demand water balance, (2) to identify alternative management strategies, and (3) to evaluate future infrastructure improvements. Comparisons of supply and demand were made for year 1990, 1995, 2005 and 2015 to quantify and locate supply deficits assuming the extension of current policies regarding water management and infrastructure. Alternative policies and potential infrastructure projects were tested in the WEAP model to identify methods of alleviating projected supply deficits. Among the water management alternatives tested were rate increases as a means of demand management, increased reuse in industry, decreased loss rates, increased reliance on underutilized sources, and artificial recharge of an overexploited aquifer using a recharge basin.

The Rio San Juan watershed drains 32,600 km^2 (12,586 mi^2), spans three states in northern Mexico, includes four major cities and eight major rivers. There are three large reservoirs in the basin and one just outside the basin which supplies the Monterrey urban area. A GIS database was developed using 1993 LANDSAT Satellite imagery processed using the ERDAS and ARC-INFO software. Results displayed with this GIS by county (municipio) included a breakdown of current and projected point of use demand, point of withdrawal water requirements, and supply sources.

California Conjunctive Use Management. Preliminary studies suggest that a statewide conjunctive water use program that integrates surface and groundwater storage in California could result in up to 1 million acre-feet of additional water per year. This expanded yield of the developed water system could be used for environmental restoration as well as other beneficial

uses. The Natural Heritage Institute (NHI) is coordinating a statewide effort aimed at refining the estimates of additional water, and building a consensus among interest groups that would benefit from this increased yield. NHI is identifying potential conjunctive use sites, devising strategies for overcoming bottlenecks in the statewide distribution system, and modeling alternative conjunctive use strategies using WEAP, the Water Evaluation and Planning System. A geographic information system will be integrated into the analysis. The modeling system will be developed as a flexible, strategic planning tool for future water management issues in California.

State of Alabama. WEAP is being used by the Alabama Office of Water Resources initially to model the ACF and ACT river basins. The objective is to help Alabama better participate in an interstate water allocation project with Georgia and Florida. WEAP will later be used for general water resources planning in those basins as well as other basins in Alabama.

Merrimack River. The Souhegan River Watershed Study is part of the Merrimack River Initiative to study issues and problems of the watershed in a holistic, resource-based manner using the watershed as the management unit rather than singling out a specific portion of a river. WEAP is being applied through the Merrimack River Watershed Council to study flow and water quality issues in the Souhegan watershed. The Souhegan River drains a watershed of 170 square miles in southern New Hampshire and northern Massachusetts. Water use in the watershed is agricultural (10%), residential (20%), recreational/conservation (7.9%), institutional/commercial/industrial (2.2%), and undeveloped (59.9%). The study includes a comprehensive collection and assessment of watershed information which is entered into a GIS mapping program. The WEAP part of the study is serving as a pilot for a possible larger application by the New Hampshire Department of Environmental Services and the Massachusetts Department of Environmental Protection in their respective states.

North Dakota Water Commission. The North Dakota Water Commission is testing a new (1995) version of WEAP for possible application to the Red and Cheyenne River Basins and later throughout the state. The principal objective is to model supply and demand where demand includes an extensive water rights system that involves priority of water use. WEAP has the capability to assign priorities between demand sites, between local and river supply sources and between river withdrawals.

REFERENCES

U.S. Army Corps of Engineers. 1994. *Accounting for Water Supply and Demand: An Application of Computer Program WEAP to the Upper Chattahoochee River Basin, Georgia*, Hydrologic Engineering Center, Davis, California.

Hayes, Richard J., Katherine A. Popko, and William K. Johnson. 1980. *Guide Manual for Preparation of Water Balances*, Hydrologic Engineering Center, Davis, California.

Tellus Institute. 1995. *WEAP, Water Evaluation and Planning System, User Guide for Version 95.0*, Boston, Massachusetts.

Table 1
Inventory of Supply and Demand Features in the Upper Chattahoochee River Study Area

Study Area

16 Counties
2 Hydrologic Units (HU #1 and #2)
1 Sub-basin (Lake Sidney Lanier to Fairburn Gage)
25 River Reaches (River Segments between Two Nodes)

River Supply

1 Main River (Upper Chattahoochee River)
1 Main River Reservoir (Lake Sidney Lanier)
2 Hydroelectric Power Plants (Lake Sidney Lanier and Morgan Falls)
1 Tributary (Sweetwater, Cr.)
11 Confluences
- 4 Gaged Streams (Suwanee Cr., Big Cr., Sope Cr., Peachtree Cr.)
- 6 Ungaged "Local" Streams (Norcross, Roswell, Morgan Falls, Atlanta, Hwy 280, Fairburn)

13 Withdrawal Nodes
- 8 Withdrawal and Return Flow (US Suwanee Cr., DS Johns Cr., Holcomb Br. Rd., Roswell Rd. Br., Johnson Ferry Rd., US Peachtree Cr., Jackson Pkwy., Cambellton Rt. 166)
- 5 Return Flow Only (Wilson Cr., Marietta Blvd., Hwy 20, Cobb/Douglas Co. Line, Sweetwater Cr./Camp Cr. Wastewater Plants)

4 Instream Flow Requirements (Water Quality-1, Water Quality-2, Fish and Wildlife, Water Quality-3)
1 Minimum Downstream Requirement (Fairburn Gage)

Local Supply

5 "Other" Sources (Soque River, Turner Cr., Camp Cr., Yahoola Cr., Sweetwater Cr.)
1 Groundwater Source (Blue Ridge/Piedmont Aquifer)
0 Local Reservoirs
1 Out-of-Basin Source (Lake Allatoona)
1 Unaccounted Surface Water Source

Demand Sites

24 Demand Sites
- 12 Countries
- 12 Individual Sites

44 Transmission Links
10 Return Links

Demand Branches

3 Sectors (Municipal/Commercial; Industrial; Agricultural)
30 Subsectors (16 Countries; 4 Industries and Counties; 12 Counties)
56 End-uses (34 Urban, Rural, Plants; 9 Plants and Counties; 13 Hydrologic Units)
84 Water Devices (54 Plants and All; 17 Plants and Cities; 13 All)

Demand Projections

1 Base Year (1990)
2 Future Years (Years 1995 and 1999 for the AMA)
2 Growth Rates (4.94% for other then AMA Demand; 2.22% for Wastewater Return)

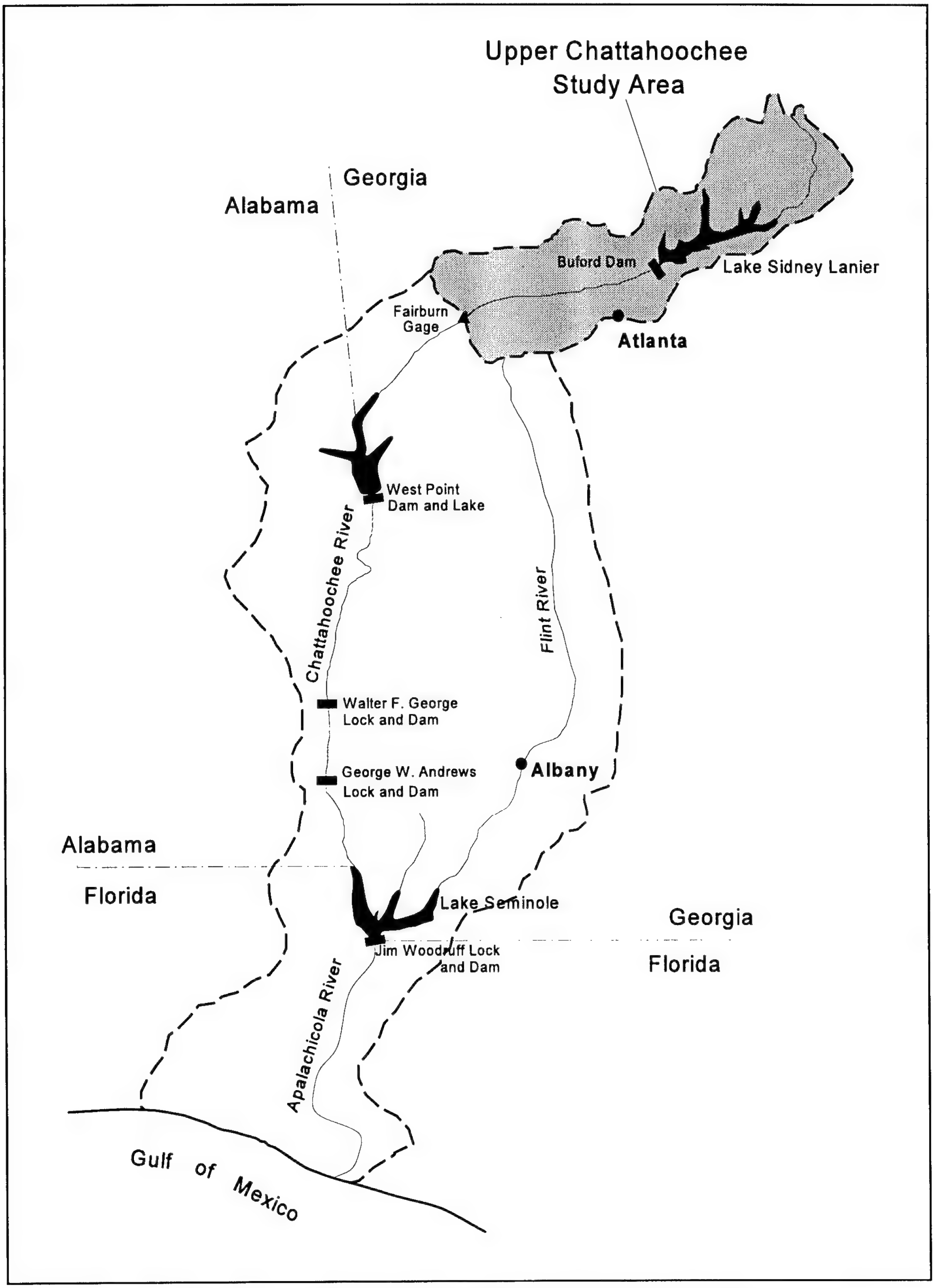

Figure 1: Apalachicola-Chattahoochee-Flint River Basin

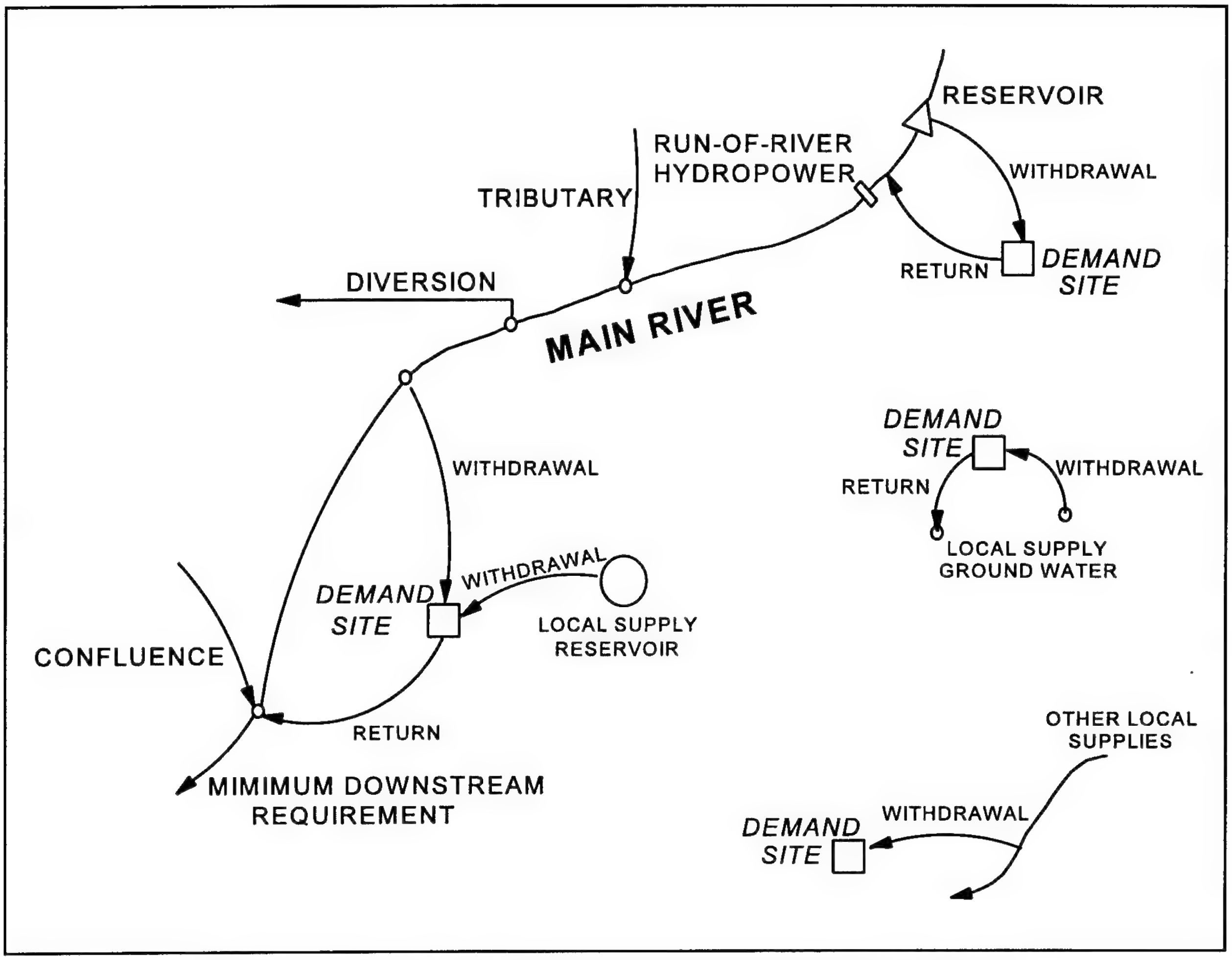

Figure 2: Supply and Demand Featuresn Modeled by WEAP

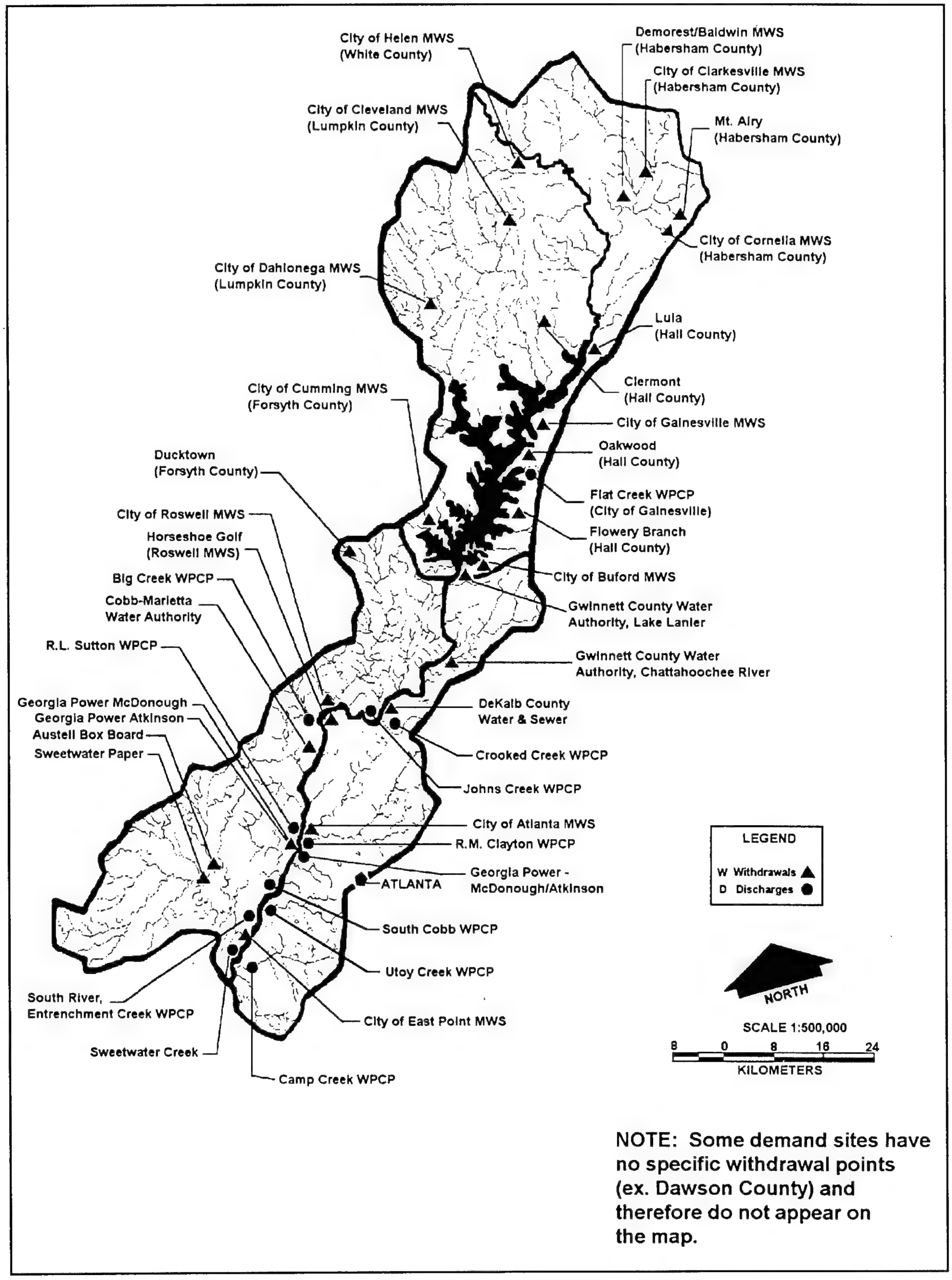

Figure 3. Principal Wastewater Treatment Facilities and Water Supply Intakes in the Upper Chattahoochee River Basin

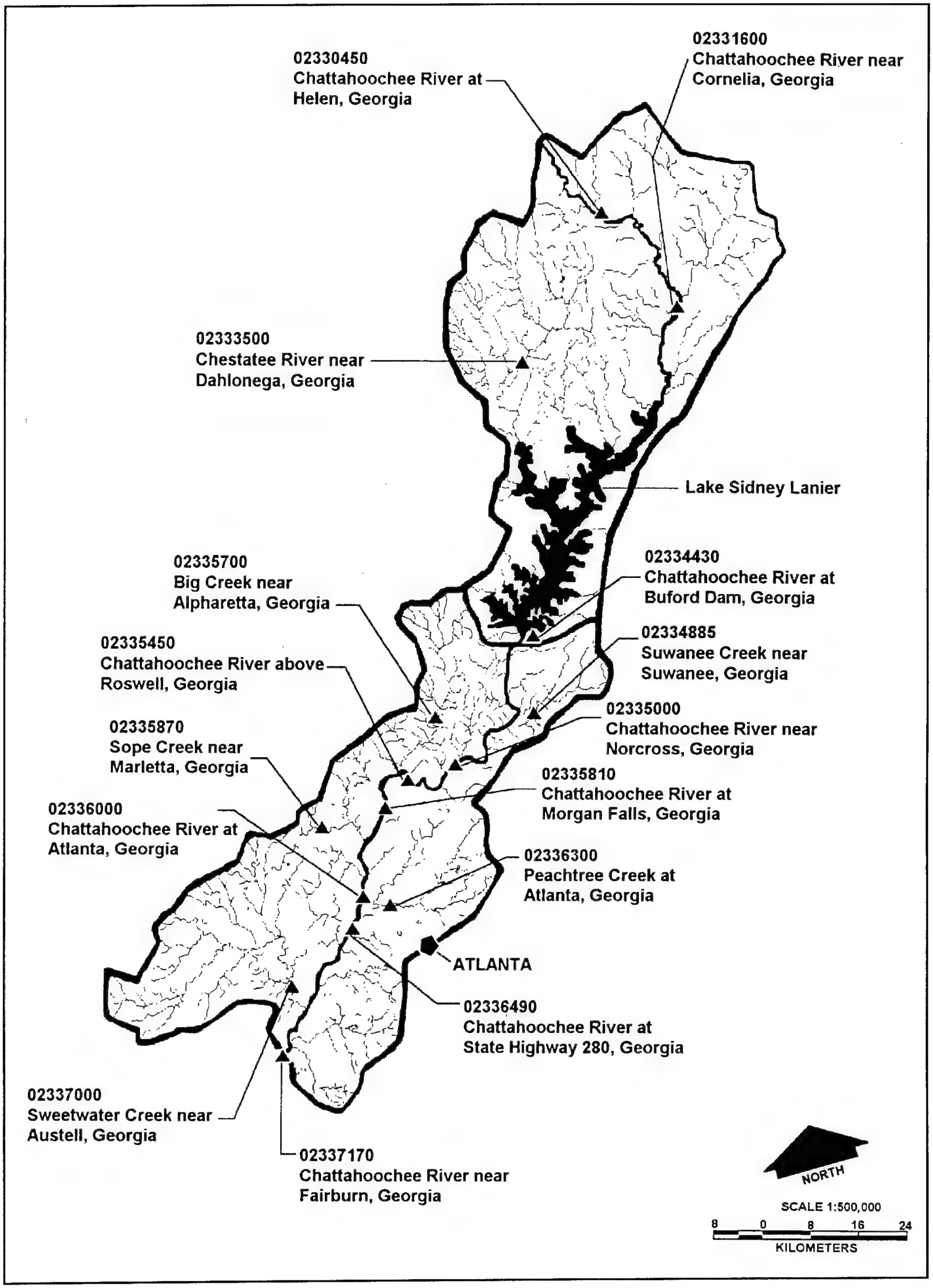

Figure 4. U.S. Geological survey Stream Gages in the Upper Chattahoochee River Basin

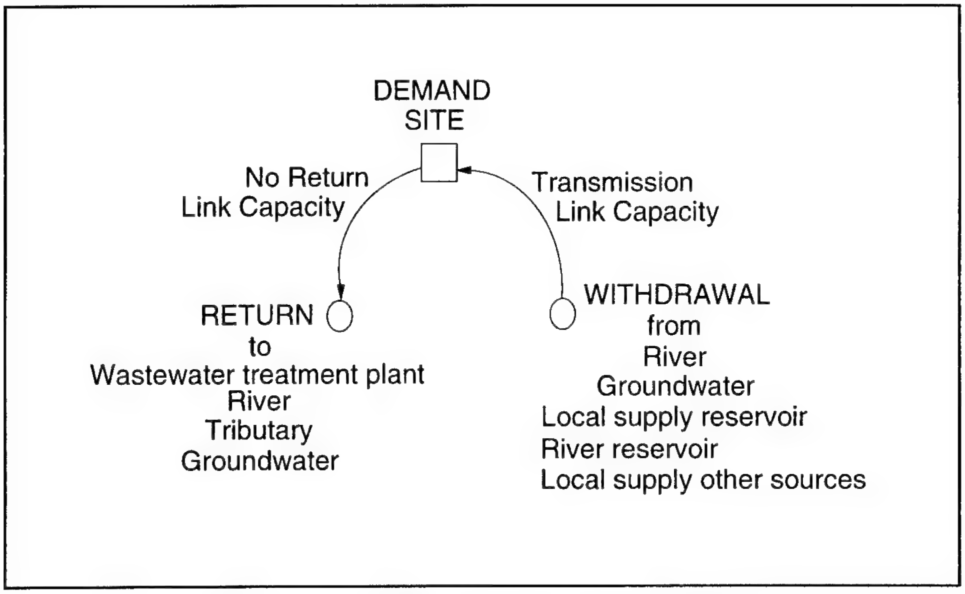

Figure 5: Typical Demand Site Features

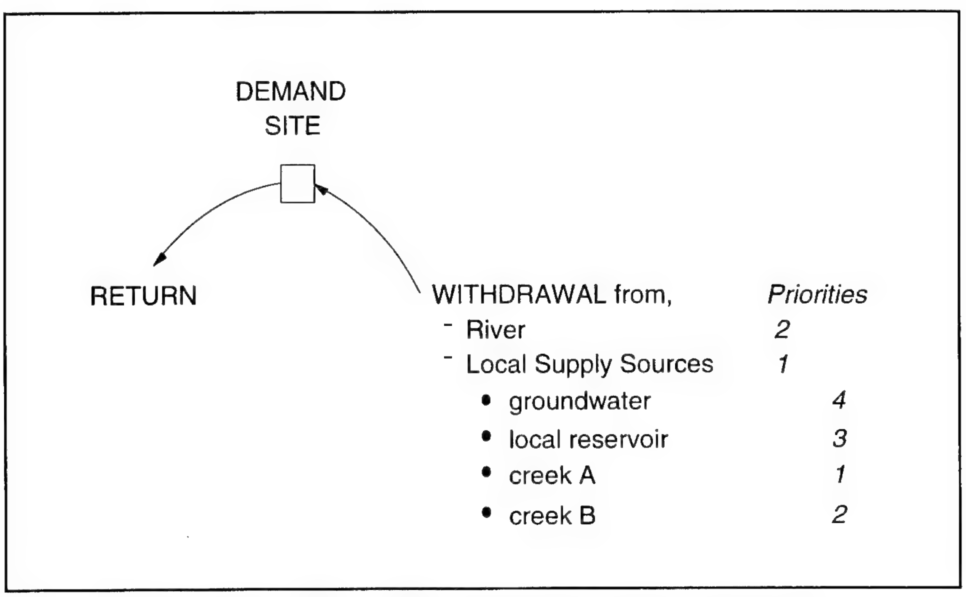

Figure 6: Priority Between Local Supply Sources

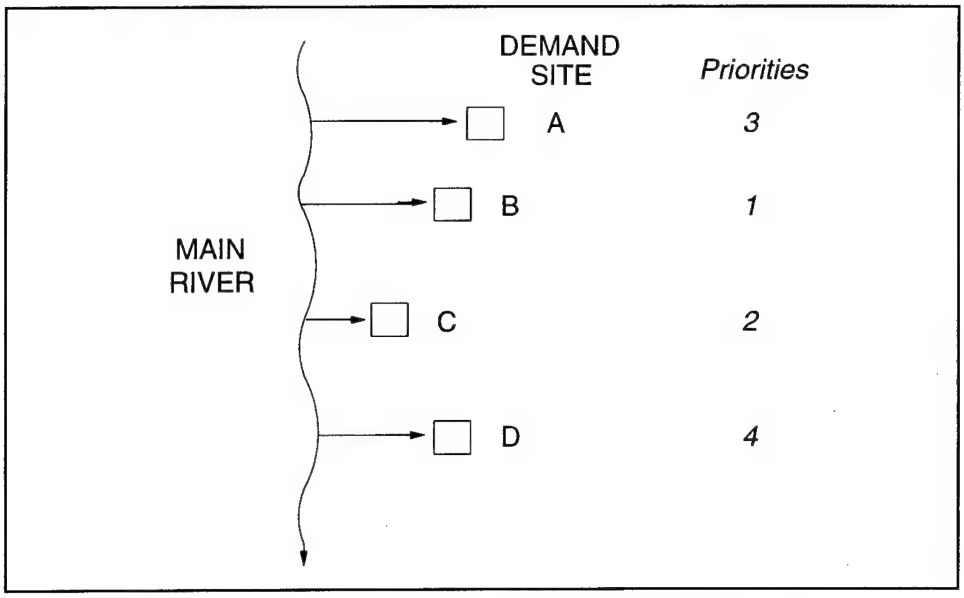

Figure 7: Priority Between Competing Demand Site along the Main River

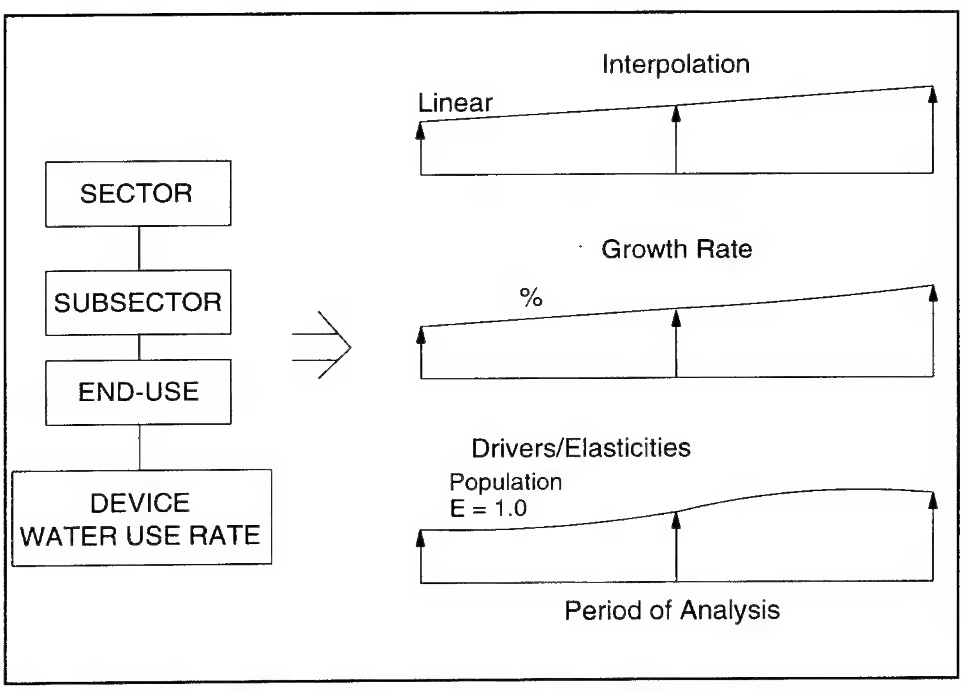

Figure 8: Demand Projection Options

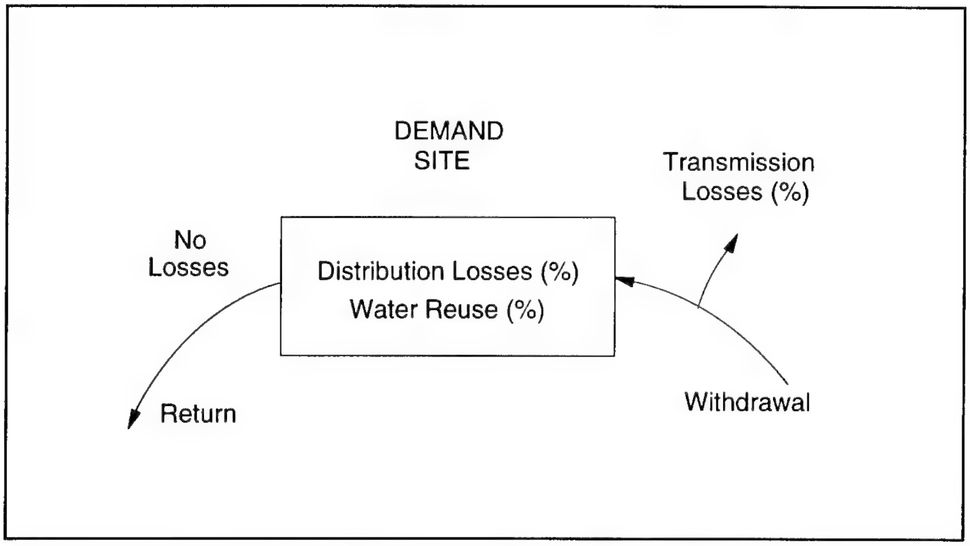

Figure 9: Losses and Reuse for a Demand Site

DEMAND RESULTS

WATER DEMAND: DEMAND SITE BY YEAR, ALL SECTORS
(MILLION CUB. METERS)

	1990	1995	1999
HABERSHAM	9.09	10.94	12.76
WHITE	2.52	3.00	3.47
HALL	3.89	4.69	5.49
GAINESVILLE MWS	17.43	22.17	26.88
LUMPKIN	2.66	3.17	3.68
DAWSON	0.01	0.01	0.01
FORSYTH	8.61	10.69	12.75
BUFORD MWS	1.02	1.38	1.67
GWINNETT	0.14	0.14	0.14
GWINET W&S LAKE	67.51	87.08	102.74
GWINNETT CHAT.	11.12	0.33	0.33
ATL/FULTON MWS	0.00	57.60	69.50
DEKALB	0.75	0.75	0.75
DEKALB CO W&S A	109.37	124.00	135.70
FULTON	2.76	2.76	2.76
ROSWELL MWS	0.86	1.13	1.34

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DEMAND Scenario: BA - BASE CASE Area: UCHAT94M

Figure 10: Demand Site by Year

DEMAND RESULTS

WATER DEMAND: DEMAND SITE BY SECTOR, 1990

(MILLION CUB. METERS)

	MUNICIPAL	INDUSTRIA	AGRICULTU	TOTAL
HABERSHAM	5.70	1.05	2.33	9.09
WHITE	1.56	0.17	0.79	2.52
HALL	2.81	0.12	0.95	3.89
GAINESVILLE MWS	15.64	1.79	0.00	17.43
LUMPKIN	1.65	0.22	0.79	2.66
DAWSON	0.00	0.00	0.01	0.01
FORSYTH	6.88	0.74	0.99	8.61
BUFORD MWS	1.02	0.00	0.00	1.02
GWINNETT	0.00	0.00	0.14	0.14
GWINET W&S LAKE	67.51	0.00	0.00	67.51
GWINNETT CHAT.	11.12	0.00	0.00	11.12
ATL/FULTON MWS	0.00	0.00	0.00	0.00
DEKALB	0.00	0.00	0.75	0.75
DEKALB CO W&S A	109.37	0.00	0.00	109.37
FULTON	0.00	0.00	2.76	2.76
ROSWELL MWS	0.86	0.00	0.00	0.86

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DEMAND Scenario: BA - BASE CASE Area: UCHAT94M

Figure 11: Demand Site by Sector

WEAP SUPPLY PROJECTIONS

STREAMFLOW: FLOW

1990

(CMS)

	ANNUAL	JAN	FEB	MAR	APR	
SWEETWATER CRK						
EAST POINT MWS	10.88	16.85	9.92	40.72	21.14	12
U.Chattahoochee						
LAKE LANIER	72.21	75.22	53.84	209.05	94.75	67
US SUWANEE CRK	71.83	74.91	53.53	208.69	94.38	66
SUWANEE CR	73.96	78.10	55.47	216.41	97.89	69
NORCROSS LOCAL	79.26	85.28	60.41	231.66	105.62	76
ROSWELL LOCAL	81.81	88.96	62.76	240.18	109.63	79
DS JOHN'S CREEK	81.79	88.96	62.75	240.13	109.61	79
HOLCOMB BRDG RD	78.13	85.57	59.44	236.73	106.06	75
BIG CR	82.15	91.21	62.71	251.17	112.10	80
ROSWELL RD BRDG	82.13	91.20	62.70	251.12	112.08	80
WL.CK/BG.JN.WW	82.44	91.19	63.02	251.33	112.36	81
MORGAN LOCAL	87.41	97.92	67.16	267.58	119.50	87

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SUPPLY Scenarios: BA, BA, BA Area: UCHAT94M

Figure 12: Streamflow: Flow

WEAP SUPPLY PROJECTIONS
INSTREAM FLOW SUFFICIENCY
1990
(MILLION CUB. METERS)

	JAN	FEB	MAR	APR	MAY	
Name: U.Chattahoochee, US PEACHTREE CR						
Req: WATER QUALITY, wastewater dilut						
ACTUAL FLOW	263.34	157.33	744.78	311.82	232.40	166
INSTREAM REQ.	56.89	51.38	56.89	55.05	56.89	55
DEVIATION	206.45	105.95	687.89	256.77	175.51	111
Name: U.Chattahoochee, ATLANTA LOCAL						
Req: WATER QUALITY, 7Q10 flow						
ACTUAL FLOW	276.82	169.24	757.89	325.00	246.75	181
INSTREAM REQ.	68.27	61.66	68.27	66.06	68.27	66
DEVIATION	208.55	107.58	689.63	258.93	178.48	115

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SUPPLY Scenarios: BA, BA, BA Area: UCHAT94M

Figure 13: Instream Flow Sufficiency

WEAP SUPPLY PROJECTIONS
DEMAND SITE MASS BALANCE
1990
(THOUSAND CUB. METERS)

	ANNUAL	JAN	FEB	MAR	APR
HABERSHAM					
INFLOW FROM:					
LOCAL SUPPLY SOURCES					
Soque Riv 10.5	1321.51	112.24	101.38	112.24	108.62
Camp Cr 3.5	3182.82	313.76	283.39	313.76	303.63
GW - BLUE R/PDM	1561.78	132.64	119.81	132.64	128.37
SW - UNACC'TED	0.00	0.00	0.00	0.00	0.00
TOTAL INFLOW	6066.11	558.64	504.58	558.64	540.62
OUTFLOW TO:					
CONSUMPTION	-6066.11	-558.64	-504.58	-558.64	-540.62

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SUPPLY Scenarios: BA, BA, BA Area: UCHAT94M

Figure 14: Demand Site Mass Balance

WATER MANAGEMENT AND THE CENTRAL AND SOUTHERN FLORIDA PROJECT

by

James Vearil, Sue Sofia, and Keith Jones[1]

INTRODUCTION

The Central and Southern Florida (C&SF) Project is a large, multipurpose water resource project designed and constructed by the Jacksonville District, U. S. Army Corps of Engineers and covers an area of about 15,000 square miles. Major features within the Project area include Kissimmee River Basin, Upper St. Johns River Basin, Lake Okeechobee and Outlets, East Coast Area, Everglades Agricultural Area, Water Conservation Areas, Everglades National Park, and Big Cypress National Preserve. The local sponsors for this project are the South Florida Water Management District (SFWMD) and the St. Johns River Water Management District (SJRWMD) for the Upper St. Johns River Basin portion. The Corps of Engineers operates and maintains project works on Lake Okeechobee and its outlets and the main outlets for the three Water Conservation Areas. The SFWMD and SJRWMD operate the remainder of the project based on Corps specified criteria. The Congressionally authorized project purposes include flood control, irrigation, municipal and industrial water supply, preservation of fish and wildlife, water supply to Everglades National Park, prevention of saltwater intrusion, recreation, and navigation. Water control plans and criteria for the project are developed by the Jacksonville District, in conjunction with SFWMD and SJRWMD, and must take into account the various, and often conflicting project purposes. SFWMD and SJRWMD are responsible for allocation of water from project storage, except where mandated by Federal law. The authors will share some thoughts and experiences in water management, and conflicting use resolution derived from their experiences as water managers with the Central and Southern Florida Project.

WATER MANAGEMENT

Compromise is a basic factor in multi-purpose water resources project design and operation (Viessman and Welty, 1985). Rules to operate water resource systems are generally based on a trade-off among the effects of different alternatives (Linsley and Franzini, 1979). The practical approach has been typically to analyze various factors ahead of time and produce operating rules which generally produce results close to optimum. These operating rules for U.S. Army Corps of Engineers Projects are contained in Water Control Plans, Water Control Manuals, and Emergency Action Plans. Water Control Plans must blend all the varied, and conflicting purposes (U.S. Army Corps of Engineers, 1987). Loucks (1992) points out the water managers dilemma, "Everyone who has had any introduction to water resources planning and management knows you cannot design or operate water resources systems without making compromises over competing purposes (such as hydropower or flood control) or competing objectives (such as who

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benefits or who pays, and how much and when)... Planning and managing involves not only decision making, but also developing among all interested and influential individuals an understanding and consensus that legitimizes the decisions and enhances successful implementation." Vlachos (1993) identified four broad areas of transformations he feels are occurring in the field of water resources: (1) Conceptual - complexity, chaos, uncertainty; (2) Methodological - decision support systems, GIS, risk analysis, computational power, multi-objective analysis; (3) Organizational - participatory, anticipatory, contingency planning; (4) Substantive - new focus, shifting concerns, shifting priorities.

PROJECT BACKGROUND

The Comprehensive Plan contained in House Document 80-643 (U.S. Congress, 1948) noted, "The plan as a whole and each of its major features are multi-purpose in concept and design. Accordingly each feature of the plan contributes to the realization of the primary benefits through flood protection, drainage, and the control of water... In brief, it is believed that this comprehensive water control plan and the national park plan are complimentary features of Federal activity necessary to restore and preserve the unique Everglades region." The Central and Southern Florida (C&SF) Project covers an area of about 15,000 square miles in Central and South Florida; and contains over 1,000 miles of project levees, over 1,000 miles of project canals, 30 pump stations, and over 200 water control structures (see Figure 1 and 2). The hydrology and hydraulics of the C&SF Project are affected by the flat hydraulic gradients, indeterminate drainage divides, periods of extremely intense rainfall, high evapotranspiration rates, overland sheet flow, subsurface flow, and occurrence of hurricanes. Average annual rainfall varies from 48 to 62 inches across the project area, with about two-thirds of the rainfall normally occurring from May through October. The C&SF Project area contains some sizable, fast growing population centers (West Palm Beach-Ft. Lauderdale-Miami, Orlando, Ft. Myers), substantial agriculture development (citrus, sugar, winter vegetables, dairies, cattle); and the Everglades National Park, Big Cypress National Preserve, Loxahatchee Wildlife Refuge, Biscayne Bay National Park, Florida Keys National Marine Sanctuary, and a number of State Parks and management areas. This leads to competition and conflict for and about urban, agricultural, and environmental needs for water.

Kissimmee River Basin

The Kissimmee River Basin is the largest watershed providing surface water delivery to Lake Okeechobee. The total basin encompasses about 3,000 square miles. The purpose of the general plan for these project works was to relieve flooding and minimize flood damages, largely in the upper Kissimmee basin. This was to be accomplished partially by flood storage in the lakes of the upper basin and partially by providing the capability to more rapidly remove the flood water from the basin when necessary. The lake regulation schedules have been developed for flood control, navigation, agricultural water supply, and environmental enhancement.

Lake Okeechobee

Lake Okeechobee is a large (approximately 730 square miles), natural, freshwater lake in Southern Florida with a drainage area of about 5,650 square miles. When lake levels exceed the

regulation schedule, flood control releases are made from the lake. When the lake level is below schedule, releases are made from the lake as needed for water supply, navigation, prevention of saltwater intrusion, and environmental enhancement. Levees completely encircle the huge lake except where they tie to high ground on either side of Fisheating Creek. Structures through the levee are closed completely in advance of a hurricane or tropical storm to maintain the integrity of the levee during a wind tide. Outlet capacity from the lake is small compared to the immense storage capacity of the lake. Regulatory outlets from the lake are the St. Lucie Canal, Caloosahatchee River, and the Agricultural Canals. The shallow bottom topography of Lake Okeechobee, combined with the long fetch, can result in significant wind tides on the lake. The principle factors that determined the required levee grades around Lake Okeechobee were lake level prior to the hurricane, and the wind tide and wave-runup expected during the hurricane.

Water Conservation Areas and Everglades

The three Water Conservation Areas (WCA Nos. 1,2,3), located south and east of Everglades Agricultural Area (EAA) and west of the urbanized East Coast, comprise an area of about 1350 square miles. The three WCA's make up a large segment of the original Everglades. Flow is generally slow across the WCA's due to flat slopes and relatively dense vegetative cover, and significant backwater effects can develop. The Water Conservation Areas (WCA) are regulated to provide flood control; water supply for agricultural irrigation, municipalities and industry, and Everglades National Park; regional groundwater control, and prevention of saltwater intrusion; enhancement of fish and wildlife; and recreation. Prior to drainage, the Florida Everglades was up to 60 miles wide and stretched from Lake Okeechobee southward to the southern tip of the state between Florida Bay and the Ten Thousand Islands area. The Everglades Agricultural Area (EAA) is a large (about 1100 square miles), highly productive agricultural area comprised of organic peat or muck soils south of Lake Okeechobee. The three Water Conservation Areas, located south and east of the EAA and west of the urbanized East Coast, comprise an area of about 1350 square miles. The three WCA's make up a large segment of the original Everglades. Water Conservation Area No. 1 is designated as the Arthur Marshall Loxahatchee National Wildlife Refuge. Water Conservation Areas No. 2 and 3 are public hunting and fishing areas; they comprise the Florida Game and Fresh Water Fish Commission Everglades Wildlife Management Area. The effects of the regulation schedules on fish, wildlife, and vegetation in the WCA's were and are important considerations in determining regulation schedules' shapes and ranges. Everglades National Park lies south of the WCA's, covers about 2200 square miles, and consists of five major physiographic subzones: Shark River Slough, Rocky Glades, Broad River/Lostsmans River, Coastal Swamps and Lagoons, and Cape Sable. The Big Cypress National Preserve lies to the west of WCA No. 3A.

Lower East Coast

The Biscayne Aquifer is a surficial, highly permeable, wedge shaped aquifer that is about 200 feet thick at the coast but thins to a few feet near its western boundary 35 to 40 miles inland. This aquifer provides water for municipal and industrial (M & I) water supply and agricultural irrigation along the southeast coast. The coastal spillways prevent a saltwater wedge from moving up the canals, and maintain sufficient freshwater head to prevent saltwater intrusion in the aquifer.

Upper St. Johns River Basin

The Upper Basin project is designed to provide flood protection for expanding agricultural and urban activities within the basin, agricultural water supply, and significant environmental benefits. For management purposes, two types of areas are distinguished; marsh conservation areas, and water management areas. The purposes of the marsh conservation areas are to temporarily retain flood water, provide long-term water conservation storage, and to restore and preserve floodplain wetlands. Water management areas temporarily retain flood waters from agricultural lands and segregate farm discharges from the marsh conservation areas. The project consists of six major areas divided by levees and used for water management purposes. These are the Fort Drum Marsh Conservation Area (FDMCA), the Blue Cypress Marsh Conservation Area (BCMCA), the Blue Cypress Water Management Area (BCWMA), the St. Johns Water Management Area (SJWMA), and a system of structures and levees located in the area between State Road 60 and the Fellsmere Grade.

POLITICAL/INSTITUTIONAL

The focus of governmental efforts in planning, developing, and operating water resources projects is usually improvement in national or regional welfare (Meta Systems, 1975). Madison (1788) felt that, "the public good, the real welfare of the great body of people, is the supreme object to be pursued; and that no form of government whatever has any other value than it may be fitted for the attainment of that object." Governmental policy making is complicated by the size of government, number of participants (in and out of government), the separation of institutions to share powers, and the vast range and complexity of issues (Ripley and Franklin, 1984). The United States Congress authorizes project purposes at the time the project authorizing legislation is passed. Additional purposes are sometimes later added, deleted, or modified by Congress. Congress also passes general legislation that applies to water resource projects (Corps of Engineers, 1990). For example, authorized project purposes for the Central and Southern Florida (C&SF) Project include flood control, water supply, preservation of fish and wildlife, major drainage and water control, water supply to Everglades National Park, recreation, prevention of saltwater intrusion, preservation of Everglades National Park, and groundwater recharge.

Specific procedures must be followed before government agencies can make decisions. For example, Section 310 of the Water Resources Development Act of 1990 requires the Corps of Engineers to provide significant opportunities for public participation in developing or revising water control plans. The process to revise water control plans can involve a number of actions such as public involvement, coordination with Fish and Wildlife Service, preparation of an Environmental Assessment or Environmental Impact Statement, interagency coordination, and so forth. We have found that for Water Control Plan changes the National Environmental Policy Act (NEPA) provides a process to facilitate public participation, analyze alternatives, and then document the final decision.

These activities are important to the development of the water control plan. However, if consensus is not reached it may be difficult or impossible to revise or modify the water control plan. An inability to reach agreement could lead to "policy gridlock" (Light and Heaney, 1990).

In response to our litigious society, legal issues are requiring increasing attention in water management. Budiansky notes, "In the age of deep pockets the act of God is passe - you can't put him on the stand." Water control management is among the Corps of Engineers activities that lead to decisions that are potential sources of disputes. Currently many of the disputes arising in the activities of the Corps are resolved through litigation or other highly adversarial processes. Delli Priscoli (1989a) feels that, "Unless we find better ways to resolve disputes, we will be buried by them."

There are numerous efforts in South Florida focused on interagency and multi-jurisdictional efforts in resource planning and management. For example, in September 1993 the Department of Interior, Department of Commerce, Department of Army (Civil Works), Environmental Protection Agency, Department of Justice, and Department of Agriculture entered into an Interagency Agreement on South Florida Restoration to promote and facilitate coordinated Federal actions to restore the South Florida Ecosystem. This agreement established an Interagency Task Force and an Interagency Working Group to coordinate these efforts on ecosystem management among Federal agencies; State, local, and tribal governments; and the SFWMD. In 1994, Florida's Governor created the Governor's Commission for a Sustainable South Florida to make recommendations for achieving a healthy Everglades Ecosystem that can coexist and be mutually supportive of a sustainable South Florida economy and quality communities.

WATER CONTROL PLANS

Water control plans contain the operational criteria, rules, and procedures that are used to operate the project. Water control plans should be revised as needed to meet changing conditions or demands. Flexible and robust water control plans could help in more effectively meeting customer's and user group's expectations. South Atlantic Division has been proactive and responsive in approving water plan changes and deviations to the Plans to meet the needs of our customers.

DECISION SUPPORT SYSTEMS

Water Management Decision Support Systems use a wide range of tools including computers, databases, models, data collection platforms, and visual displays (Johnson, 1986). Decision support systems are integrated computer hardware and software packages readily usable by managers and operators as an aid for making and implementing operational decisions. Software developments such as interactive models, computer graphics, GIS, expert systems, electronic mail, and multimedia systems can lead to improved communication and understanding (Loucks, 1992) and help facilitate public involvement (Johnson, 1990). The objective of the Real-Time Water Control Research Program is to develop an integrated decision support system which includes data acquisition, data processing, decision formulation and evaluation, and information display capabilities (HEC, 1994). The system would allow water managers to make intelligent, informed decisions in a timely manner. The Water Control Data Systems (WCDS) is the automated information system including hardware, software, and data collection system to support the Corps of Engineers water management mission, along with other Corps functions

such as emergency management (HEC, 1995). In our minds, the WCDS is a component of a broader Water Management Decision Support System.

The common objective of the Jacksonville District DSS, like any other DSS, is to provide timely information that supports human decision makers - at whatever level of decision making (Loucks, 1995). Due to the Districts large area of responsibility a major emphasis has been, and continues to be placed, on the automation and dissemination of data collection processes. Data collection processes occur automatically with the other federal, state, local and data collection systems and make use of several technologies including internet file transfers and World Wide Web homepages. The Jacksonville District, the SFWMD, the USGS, and the National Park Service have agreed to a Generalized Data Exchange Format developed from the modified .E format of the Standard Hydrologic Exchange Format. A factor in the usefulness of the DSS is that a meaningful form of information needed by the decision makers is made available during the window of opportunity the data is required (Loucks, 1995).

The implemented DSS has been used to demonstrate to a wide variety of people in public and private agencies and organizations and individuals that the Corps management involvement is done with current and timely information. Our customers and sponsors confidence in our management and coordination activities has improved. Development of data transfer protocols between agencies has benefitted all parties involved in similar water management activities and DSS development and implementation and fostered a sense of community. Data requests are easily and quickly complied with and analysis of historical conditions have been made possible due to implementation of HEC Data Storage System historical and realtime databases.

The Districts WCDS DSS has been under development for a period of three years. Much of the success can be attributed to the organizations realization and support of the DSS development team approach. DSS users and development team members work to bring together technical knowledge, an understanding of issues and processes being addressed, information needs, responsibilities, capabilities and preferences of the potential users (Loucks, 1995). The future Water Management DSS will take advantage of user interfaces being developed that integrate GIS spatial data and visualization, relational database, and HEC Data Storage System time series database. Other technologies with digital imagery and hypertext and CAD will be linked to the DSS. The use of realtime models and other hydrologic models and analysis tools are also of much interest to us.

To take advantage of the current and future technologies available to decision makers as decision support systems requires committing resources of time, personnel, training, and data processing equipment. Management's support of a successful implementation of any DSS using current technology will need to include technically capable development team members that understand the use of the DSS in its particular environment. How easily generic DSSs being developed can be adapted to specific environmental variables the decision makers operators under will be important to their usefulness. As long as a particular DSS is in use, there will be an interactive process of designing, implementing, evaluating, and redesigning (Loucks, 1995).

CUSTOMERS

According to the Federal Quality Institute (1991) the Total Quality Management (TQM) approach involves focusing on achieving customer satisfaction, seeking continuous and long term improvement, and involving the entire workforce. Achieving this goal requires identifying customers and their needs, and having a clear idea of how the organization plans to try and meet those expectations. Total Army Quality (TAQ) embodies the fundamental aspects of TQM (Corps of Engineers, 1993a). One of the goals in the Jacksonville District's (1993b) Vision, Goals, and Objectives (VGO) is to provide exceptional service to our customers (whether internal, external, or the public), and recognizes that this is an essential factor in any successful organization. Some of the objectives in this goal include getting to know our customer and have them know us; understand each others expectations, capabilities, and limitations; maximize opportunity for integration and participation of our customers as team members.

The National Performance Review (Gore, 1993) objective is to produce a government that works better and cost less. One of the key principles identified was putting customers first. The use of public involvement, partnering, updated and revised water control plans, and decision support systems can assist the Water Management and Meteorology Section in providing service to Jacksonville District customers as envisioned in the VGO.

PUBLIC INVOLVEMENT

Public involvement by the U.S. Army Corps of Engineers serves to help ensure that Corps of Engineers' programs are responsive to the needs and concerns of the public (Corps of Engineers, 1990). The objectives of public involvement are to provide information about Corps of Engineers activities to the public; make the public's desires, needs, and concerns known to decision makers; to provide for consultation with the public before decisions are reached; and to take into account the public's views in reaching decisions. Viessman (1991) feels that public involvement means effectively integrating public views and attitudes into water resources planning and management. He identified the following keys to public involvement: making a total commitment, partnering, education and communication, capturing society's view, communicating risk, fostering technologic awareness, providing the right forums, and taking a holistic view. The major problems that engineers and scientists often face are not technical, and public involvement and conflict management techniques help deal with these problems (Delli Priscoli, 1989b). Water managers must develop good communication skills and learn to make effective presentations.

The Government Accounting Office (1995) recently prepared a report on public participation in Federal Everglades restoration efforts. The GAO stated one of the lessons learned so far is that nonfederal stakeholders would generally prefer to present their concerns, positions, and supporting documentation, during, rather than after, development of Federal proposals to address environmental concerns. GAO noted that constraints imposed by external factors often dictate the extent to which federal agencies can involve nonfederal stakeholders in their activities. Although consensus is desirable, restoration efforts are inherently contentious. The GAO also reviewed the use of NEPA and public involvement in several Corps of Engineers' efforts in South Florida.

WATER MANAGER'S VIEWPOINT OF THE C&SF RESTUDY

The purpose of the Comprehensive Review Study, Reconnaissance Report, was to reexamine the existing Central and Southern Florida (C&SF) Project to identify possible structural or operational modifications that could be essential to the restoration of the Everglades and Florida Bay ecosystems while providing for other water related needs. The objective of the reconnaissance study was to identify problems and opportunities, formulate alternative plans, evaluate conceptual alternative plans, and recommend, if feasible, further detailed studies. Given the complexity of the problems to be considered in this study and the desire to use the skills of specialists in other agencies, a multi-agency approach was developed to complete the formation of the study team. Multi-agency staffing was essential in order to facilitate the flow of needed information among agencies, and, more importantly, to achieve buy-in and ownership by the key public agency stakeholders. Besides various Corps personnel, the study team included personnel from other agencies such as the South Florida Water Management District, the National Park Service, the U. S. Fish and Wildlife Service, and the National Marine Fisheries Service (U.S. Army Corps of Engineers, 1994).

Modeling efforts for the C&SF Study focused mainly on an object-oriented program called STELLA II. In recent years, object-oriented computer modeling has been applied to water management, hydrology, and hydraulic problems. The building and use of these models is extremely user-friendly and time-efficient. As part of the C&SF Study, an object-oriented model was developed to evaluate various plans that were being considered as potential solutions. The model includes inflows to Lake Okeechobee and essentially all routings south and east of the lake. The model was used to evaluate water budgets in the region so that many plans could be evaluated. Once the existing conditions model was developed, the model was modified to include one or more new components intended to improve water management. Component examples include creation of new storage areas, increases in canal capacities, and changes in operational constraints and rules. The plans that required evaluation were typically different combinations of components designed to improve water resources and water management (Punnett, 1995).

The results were used to determine future water control features essential to hydrologic restoration and water supply. Perhaps the greatest value associated with object-oriented modeling is in the ability to make quick, easy, and significant changes to the model (Punnett, 1995).

Public Involvement in the Restudy

The overall strategy for public involvement was an attempt to bring all of the elements available to focus on a communications effort which would solicit information from the public for the study team, and then provide feedback to the public on how the information was used. The framework used for public involvement included three rounds of participation at workshops and meetings. In all rounds, extensive efforts were made to identify stakeholders and develop a comprehensive mailing list.

The first round of public involvement solicited the views of stakeholder interest groups and the public at large regarding the identification of problems and opportunities. In the second round, interest groups and the general public were asked to provide their ideas for meeting each of the study's planning objectives. In the third round, during the study's closing months, interest groups and the general public provided their views on the results of the reconnaissance study concerning the identified problems and opportunities and proposed recommendations regarding the next phase of study (U.S. Army Corps of Engineers, 1994).

The workshops were scheduled in locations throughout South Florida in an attempt to cover the regions and the people that would be most affected by modifications to the project. The following list includes some of the major groups and/or regions. Keep in mind that the comments are not meant to offend, but to convey the diverse needs and desires of the affected areas:

(1) the farmers of the Everglades Agricultural Area, who consider themselves the "first environmentalists" and want their children to have the same opportunity to make a living from the land,

(2) Lake Okeechobee, its wildlife and littoral zone,

(3) the Kissimmee River Valley,

(4) the Lower East Coast urban dwellers, five million strong, all clamoring for fresh winter vegetables and unlimited, clean drinking water,

(5) the environmental activists,

(6) the estuaries, including the St. Lucie River and the Caloosahatchee River, whose estuarine habitat is threatened by large freshwater releases from Lake Okeechobee,

(7) the Water Conservation Areas, wildlife habitats threatened by either too little or too much water,

(8) the Big Cypress National Park,

(9) residents who live along project areas who want to maintain the status quo,

(10) the Miccosukee and Seminole Indian Tribes, who believe their tribal way-of-life may be threatened,

(11) the Everglades National Park, the jewel of Florida, sometimes gasping for water,

(12) Taylor Slough and Shark River Slough, only remnants of the originals,

(13) Florida Bay, partially covered with algae, the fish and plants are dying or gone, and some fishermen have already sold their boats, and

(14) the Florida Keys, whose economic stability may be threatened because the tourists won't come if the water isn't blue.

Because of the complexity and intense public interest focused on this study, a different approach to public interaction was necessary. The "business as usual" method was discarded in favor of a more open process which would hopefully generate a spirit of cooperation between everyone involved. The team requested input to the planning process before any concrete results were known. The participants were informed of the study's progress through monthly newsletters and three rounds of workshops over an eighteen month period.

One of the techniques utilized in the workshops was known as the "wall walk". Meeting participants were asked to answer three questions on a "yellow sheet" that concerned problems and opportunities relative to the natural resources of the South Florida ecosystem. They were then directed to write their most significant responses on flip charts that were stationed along the wall.

The "wall walk" incidentally provided attendees with opportunities to not only read but also to discuss ideas with others. This was an especially important aspect of the Fort Lauderdale and Miami "wall walks" where several highly charged exchanges among participants from urban and agricultural areas appeared to be the beginning of personal understandings among people who were traditionally in conflict with one another (Sanders and Orth, 1995).

The technique is user-friendly and accessible to a wide variety of participants. People who attended the workshops appeared to enjoy the process and accept its results. Many were particularly pleased with being asked to publicly display their responses on the flip charts, and then quickly being able to see and compare how others responded. It provided a forum for participation which did not entail public speaking which can be a deterrent (Sanders and Orth, 1995).

Useful Techniques Learned

Workshops. One of the most important lessons learned during this study was that the public appreciates being involved in the process from the beginning, before the ultimate decisions have been made. The monthly newsletters were very helpful in keeping people informed of the study team's progress between workshop rounds. Many participants praised the techniques utilized in the workshops.

The idea of asking people with local "knowledge" to contribute to the planning process also worked well. They made several suggestions that were beneficial to the development of some of the alternative plans.

Because the Study Team went out early and asked people what they thought, provided feedback on what was heard, and then used it to move forward with the study, the process helped build a basis of understanding and trust between the team and the public. Additionally, because the venue was open and the process provided opportunities for people from varying backgrounds to come together, either at a table or at the flip charts, there was a greater understanding of the

common feelings which were among the different groups. While the process is not meant as a consensus building effort, the sharing of these common concerns is one stepping stone to a widely acceptable solution (Sanders and Orth, 1995).

On the water management level, this workshop technique could prove to be an effective procedural tool when presenting proposed changes to existing regulation schedules, for example. In areas where government agencies are not highly regarded due to past conflicts and purported "highhandedness", this method may begin to effect an understanding by the public of the enormous challenges and difficulties involved in conflicting use resolution.

Modeling. Object-oriented modeling programs like STELLA II are inexpensive to obtain and the technique is easy to learn. The model applications are easy to understand and can be used to help non-technical groups understand system dynamics and can therefore aid in consensus building. Demonstrations of the STELLA II model would be beneficial at public workshops to reveal the dynamics of a system in an uncomplicated way. Although modeling covers many disciplines, it clearly benefits water resource planners and managers.

ADAPTIVE MANAGEMENT

Water resources and environmental planning and policy making typically are influenced by the breadth of impact, uncertainty, scarcity of causal evidence on which to base a plan or policy, and the multi-objective and multi-institutional involvement (Loucks et al., 1985). The Science Subgroup (1994) describes adaptive management as a structured, iterative approach that recognizes that the information used in making decisions is imperfect and as decisions are made a process should be in place to gain better information and then adjust the decisions accordingly. Adaptive management is a decision making process based on trial, monitoring, and feedback (U.S. Army Corps of Engineers, 1994). The observation of Adler (1981) seems relevant, "The form of skepticism that wisdom recommends we adopt is the one that does not challenge the objectivity of truth, but it does enjoin us to recognize how few are the judgements concerning what is true for which we can claim certitude and finality, and how many fall in the realm of doubt where they are subject to change and correction by all the means that human beings employ in their efforts to get at the truth. In fact it is only in the realm of doubt that we engage in the pursuit of truth." The Jacksonville District is attempting to use the "adaptive management" approach in such efforts as the Experimental Program of Water Deliveries to Everglades National Park, Kissimmee River Restoration Project, and the C&SF Restudy. Monitoring and data analysis are important components in the Adaptive Management process. Our water management decision support system and WCDS is an important part of our monitoring efforts in the adaptive management approach.

The University of Florida conducted a series of workshops between 1989 and 1992 in which scientists and engineers from different agencies and universities cooperated to integrate their knowledge of the South Florida system and to screen potential Everglades restoration options (Holling et. al, 1994). This process has been called Adaptive Environmental Assessment and Management. Communication and cooperation was established by using screening level models as a device to discuss processes, issues, and opportunities across agency and disciplinary lines. Some of the general conclusions for Everglades restoration reached in the workshops

include: "tinkering" does not work, single quick-fix structural changes do not work, composite policies do work, and there is more than one composite policy.

CONCLUSIONS

Water managers need a number of "tools in their toolbox." A wide variety of skills ranging from verbal and written communication skills, technical skills, analysis skills, negotiation skills, management skills, innovative, creative, and flexible water management plans are needed. The water control plans and manuals must be revised as needed to meet changing conditions and demands. The water control plan and manual help insure that water resource projects are operated safely and in a manner to achieve the maximum benefits. Water management requires coordination and public involvement. Water managers must be responsive to interest and user groups. Compromises have to be struck. Decision support systems, simulation models, and optimization models are tools that could be used to improve project operations. The Next Generation Water Control Software System holds much promise for improving and enhancing Jacksonville District water management. The Water Management and Meteorology Section has a number of internal and external customers. The major problems engineers and scientists often face are not technical, and public involvement and conflict management techniques can help deal with these problems.

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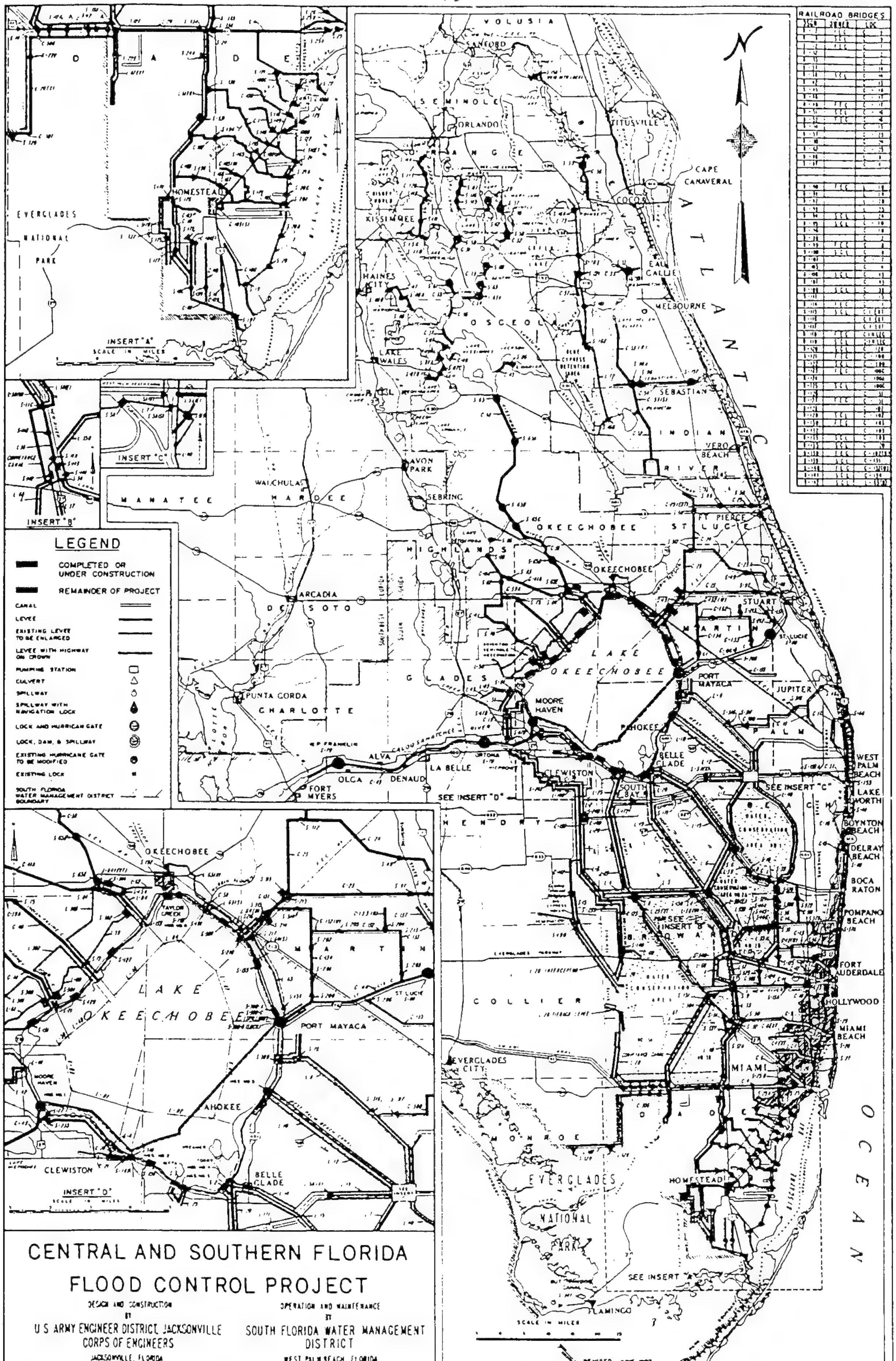

CENTRAL AND SOUTHERN FLORIDA
FLOOD CONTROL PROJECT
DESIGN AND CONSTRUCTION
BY
U S ARMY ENGINEER DISTRICT, JACKSONVILLE
CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA
OPERATION AND MAINTENANCE
BY
SOUTH FLORIDA WATER MANAGEMENT
DISTRICT
WEST PALM BEACH, FLORIDA
LEGEND
COMPLETED OR UNDER CONSTRUCTION
REMAINDER OF PROJECT
RAILROAD BRIDGES
INSERT "A"
INSERT "B"
INSERT "C"
INSERT "D"
SEE INSERT "A"
SEE INSERT "B"
SEE INSERT "C"
SEE INSERT "D"
VOLUSIA
SEMINOLE
ORANGE
OSCEOLA
INDIAN RIVER
ST LUCIE
OKEECHOBEE
HIGHLANDS
MANATEE
HARDEE
DE SOTO
CHARLOTTE
GLADES
HENDRY
MARTIN
PALM BEACH
BROWARD
COLLIER
MONROE
DADE
ATLANTIC OCEAN
LAKE OKEECHOBEE
EVERGLADES NATIONAL PARK
SANFORD
ORLANDO
TITUSVILLE
CAPE CANAVERAL
COCOA
KISSIMMEE
HAINES CITY
EAU GALLIE
MELBOURNE
LAKE WALES
SEBASTIAN
VERO BEACH
AVON PARK
WAUCHULA
SEBRING
FT PIERCE
OKEECHOBEE
ARCADIA
STUART
ST LUCIE
PORT MAYACA
JUPITER
PUNTA GORDA
MOORE HAVEN
PAHOKEE
BELLE GLADE
WEST PALM BEACH
LAKE WORTH
ALVA
OLGA
DENAUD
LA BELLE
CLEWISTON
SOUTH BAY
FORT MYERS
BOYNTON BEACH
DELRAY BEACH
BOCA RATON
POMPANO BEACH
FORT LAUDERDALE
HOLLYWOOD
MIAMI BEACH
MIAMI
EVERGLADES CITY
HOMESTEAD
FLAMINGO
TAYLOR CREEK
SCALE IN MILES

Figure 1

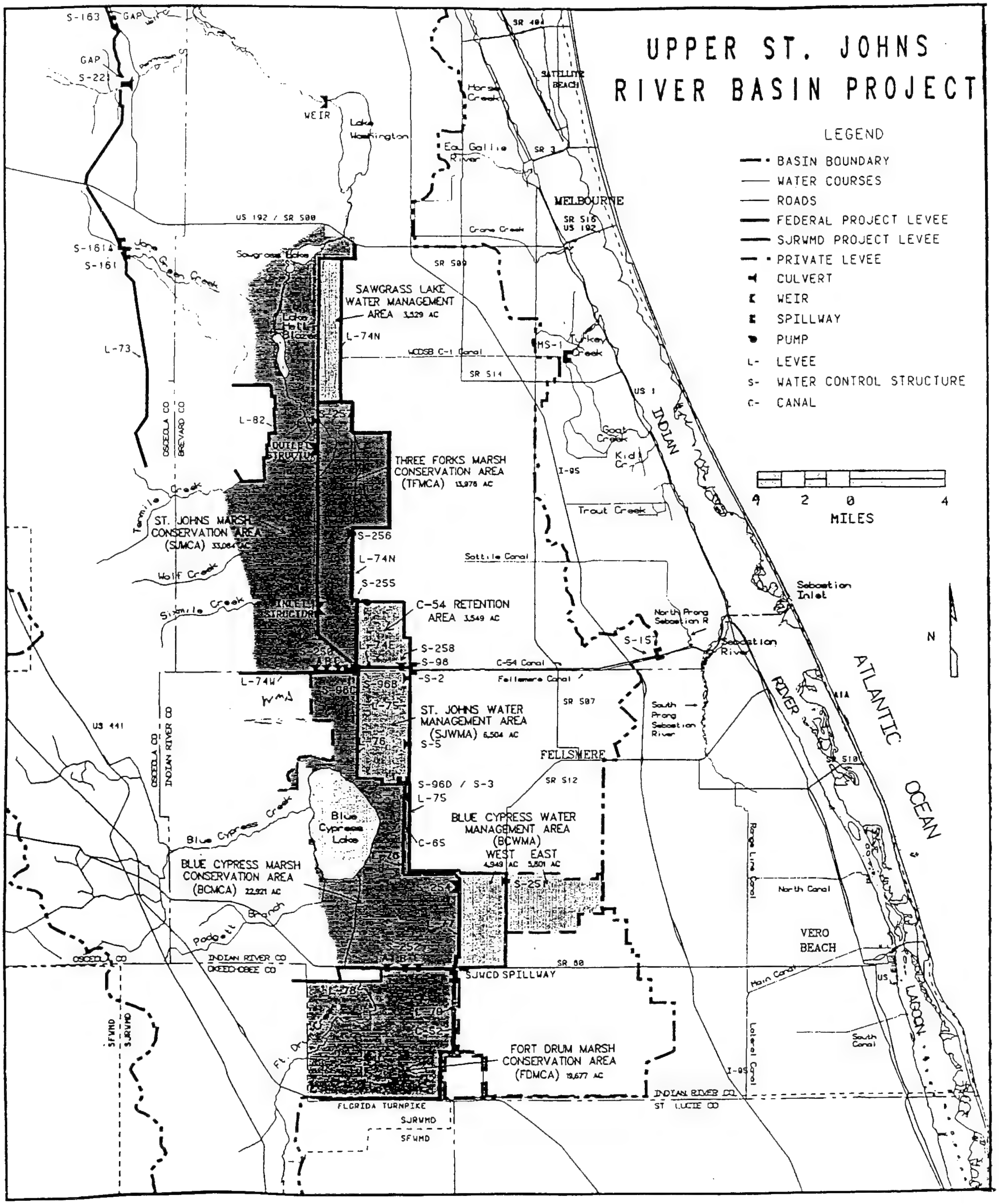
UPPER ST. JOHNS RIVER BASIN PROJECT
LEGEND
BASIN BOUNDARY
WATER COURSES
ROADS
FEDERAL PROJECT LEVEE
SJRWMD PROJECT LEVEE
PRIVATE LEVEE
CULVERT
WEIR
SPILLWAY
PUMP
L- LEVEE
S- WATER CONTROL STRUCTURE
C- CANAL
MILES
SAWGRASS LAKE WATER MANAGEMENT AREA 3,529 AC
THREE FORKS MARSH CONSERVATION AREA (TFMCA) 13,976 AC
ST. JOHNS MARSH CONSERVATION AREA (SJMCA) 33,064 AC
C-54 RETENTION AREA 3,549 AC
ST. JOHNS WATER MANAGEMENT AREA (SJWMA) 6,504 AC
BLUE CYPRESS WATER MANAGEMENT AREA (BCWMA) WEST 4,949 AC EAST 5,801 AC
BLUE CYPRESS MARSH CONSERVATION AREA (BCMCA) 22,921 AC
FORT DRUM MARSH CONSERVATION AREA (FDMCA) 19,677 AC
MELBOURNE
FELLSMERE
VERO BEACH
INDIAN RIVER
ATLANTIC OCEAN
LAGOON
Blue Cypress Lake
Sebastian Inlet
SJWCD SPILLWAY
FLORIDA TURNPIKE

Figure 2

WATER MANAGEMENT, ALLOCATION, AND CONFLICTING USE RESOLUTION
- THE TVA EXPERIENCE -

by

Arland W. Whitlock[1]

ABSTRACT

Management of the water resources of the Tennessee River Basin has been a primary responsibility of the Tennessee Valley Authority (TVA) since its creation over 60 years ago. In the early years, the focus was on the design and construction of a system of dams and locks to provide flood control, navigation, and hydropower generation to the region. These operating priorities served both TVA and the Tennessee Valley well for over 50 years. However, as basic needs were met, society increased the value of other benefits, such as the environment, recreation, water quality and aesthetic beauty.

The challenge to TVA was to recognize what was happening and change with the demand and remain a leader in operating a water control system to meet the needs that society values. By the 1960's the primary focus of water resource development was rapidly changing from construction to resource management. By the early 1970's TVA was working with state and federal agencies to look at water quality issues, such as minimum releases from dams and implemented changes in reservoir operating guidelines in response to demands for more desirable recreational levels. By the early 1980's national trends made it clear that TVA should accelerate its efforts in addressing the impact of its reservoir operations on water quality and recreation from a few pilot programs to a system-wide effort. In response to these needs, as well as to address increasing environmental regulations, the TVA Board of Directors authorized a study of the priorities for operating the Tennessee River system in September 1987.

INTRODUCTION

I have been asked to discuss the Tennessee Valley Authority reservoir operation comprehensive study, commonly referred to as the Lake Improvement Plan (TVA, 1990a). The recommendations of this Plan were adopted by the TVA Board of Directors in February 1991 and addressed two major public concerns: (1) the improvement of water quality and aquatic habitat and (2) enhanced recreation opportunities by providing more favorable summer lake levels. Other alternatives were identified by participants in the study, but not evaluated in detail for one or more of the following reasons (TVA, 1990): (1) they significantly reduced other benefits from reservoir operations that have strong support from the public and their elected representatives, (2) the problem or issue could be better addressed in other ways, and/or (3) they were not feasible.

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Allocation of the water resource and management of conflicting demands and uses were certainly very important in this study.

Before I discuss this topic, I would like to thank you for the opportunity to be a participant in this seminar. The topic 'Policy and Procedures for Water Management, Allocation, and Conflicting Use Resolution' are the issues today for all river basin management organizations. Conflict in use and management of water resources is increasing because the population is growing and societal needs are shifting from survival issues, such as the conventional flood control, navigation, and hydropower developments of the 1930's and 1940's to quality of life issues such as water quality, enhanced recreational opportunities, and the heightened desire to live on, or near, the water. A recent poll of people age 21 to 40 indicated that their first choice for a desirable place to live was on, or near, the water with mountains a close second.

The potential for conflict is increased because water resources are finite the number and diversity of users is growing rapidly. In addition, many existing projects operate under multi-purpose guidelines and integrated system operating policy, meaning that conditions for any one use on any single reservoir is seldom ideal. Many of us here today are public agency employees responsible for water resource management, or serve agencies responsible for it's management. We inherited, and are encumbered with operating policies and priorities of projects originally built for other purposes and enfranchised by current law. We can ask ourselves the question - where do we go from here?

In this presentation I address the allocation of water, the resolution of conflicts, and the policy and procedures that guide the management of water in the Tennessee Valley today. TVA was described by Roosevelt at the time of it's formation as a grand experiment, "..a corporation clothed with the power of government but possessed of the flexibility and initiative of a private enterprise". It is therefore fitting and appropriate in looking at water management to include those areas where TVA may have unique directives. I will end my presentation with my perspective of where water management may be headed in the future.

ALLOCATION OF WATER RESOURCES IN THE TENNESSEE VALLEY

Water allocation in the TVA reservoir system is established by broad guidelines as established in the TVA Act, Board Policy, the Lake Improvement Plan, and precedents established over a long period of time. The manager of the reservoir system is responsible for directing the impoundment and release of water on a daily basis to provide the optimum benefit from its use to the residents and visitors of the Tennessee Valley. Although the purposes for each TVA Dam was specified in the authorizing legislation, the amount of storage allocation for each of the operating objectives was left to the discretion of TVA management. The first development and operating plan (TVA, 1936b) states that the unified operation by a single agency is imperative if full benefits from system operation is to be obtained. The agency should receive rainfall and reservoir data and should dispatch water for flood control and power. Insofar as the public interests require, it should decide where and when water should be stored and when it should be released through the reservoir gates or by the generation of power.

The TVA Act also gave the Agency responsibility to "operate its reservoirs for the generation of electric energy" and "to transmit and market such power ... to assist in liquidating the cost or aid in the maintenance of the projects of the Authority". As we shall see later, this provided an opportunity for funding for conducting and implementing a study that most water management organizations do not have.

Early decisions made by the TVA Board included building navigable depths into the system by building a few large projects, which at minimum pool levels, would provide navigation depths throughout the system with minimal flow augmentation. In addition, an annual operating cycle was chosen because the Tennessee Valley was in a humid, normally water-rich area with a 50-inch average rainfall. Weather conditions change rapidly between the extremes of Bermuda highs which can produce prolonged periods of dry weather to the tapping of Gulf moisture which can bring periods of prolonged rainfall. Changing conditions meant need to change operating criteria for proper response. Flood control would be accomplished by providing the maximum amount of storage on January 1 when the threat of continued flooding at selected damage centers during the high flow season was greatest, and a lesser amount on March 15. However, the emphasis was not on how each individual project would be operated, but on how the operation of that project would benefit the region as a whole. The remaining space would be utilized on a season-by-season and case-by-case basis to provide the maximum multipurpose benefit to the region.

A set of operating guidelines are used, including guidelines for individual reservoirs, guidelines for subsets of reservoirs, and a system guideline. Looking at the system guideline (Figure 1) shows three zones; (1) the upper, or flood control zone where flood control is the primary operating objective, (2) the center, or discretionary zone where maximum multi-purpose objectives can be met, and (3) the minimum operating zone, with minimum flows and water quality the primary operating objectives. Multiday operating plans are developed each day to allocate water in a way that will provide the highest system benefit through a decision-making process including the current state of the system, reservoir guidelines, the available resource, and a detailed impact of meeting various demands in whole or in part. These demands include the traditional flood control, navigation and hydropower objectives, as well as water quality, recreation and environmental issues.

Water management strategy is implemented into the daily by utilizing general operating guidelines and a decision-making process to effectively consider all operating demands. Early decisions included a 'factor of safety' to compensate for uncertainty and a lack of operating experience. As knowledge was gained, the decision-making process was altered to allow the water resource to be utilized for additional benefits without undue risk to established purposes. The system was gradually being operated 'closer to the edge'.

ALLOCATION VERSUS PRECEDENCE

The evolution of operating procedures for a reservoir system over time establishes precedence and water managers must carefully balance opportunities for change between discretionary judgement and the liability of a 'taking' from one user to benefit other users. As Stephen Draper (Draper, 1991a) points out, the "doctrine of Stare Decisis, or being bound to

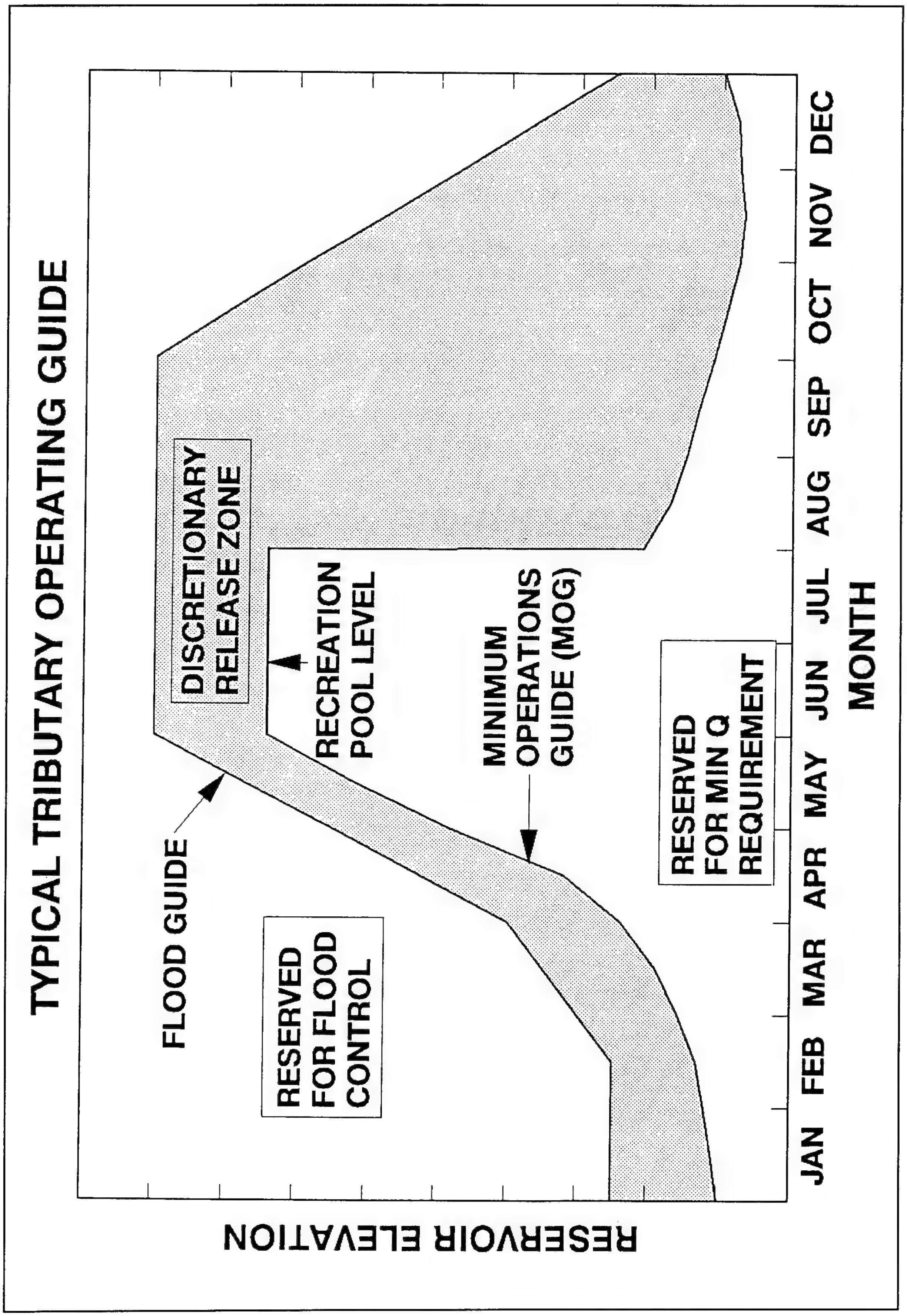
TYPICAL TRIBUTARY OPERATING GUIDE
FLOOD GUIDE
RESERVED FOR FLOOD CONTROL
DISCRETIONARY RELEASE ZONE
RECREATION POOL LEVEL
MINIMUM OPERATIONS GUIDE (MOG)
RESERVED FOR MIN Q REQUIREMENT
RESERVOIR ELEVATION
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH

Figure 1

precedent when the facts are similar is so ingrained in American culture, most water managers follow established procedures from fear of litigation. Thus, once an operating criteria is established, it, in effect, becomes an allocation. When changes in operating criteria are proposed, or implemented, it effectively changes the allocation among users. In addition, when the river can no longer sustain all users increasing demands, choices must be made among competing users. Who will allocate the water? Without consensus between all stakeholders on the front end, Draper (Draper, 1991b) states that it will be made by one of three ways; (1) allocation by the U.S. Congress under the "Commerce Clause", (2) allocation by the U.S. Supreme Court under the doctrine of "Equitable Apportionment", or (3) Allocation by the States under Article 1, Section 10 of the U.S. Constitution.

None of Draper's choices are desirable to water managers to solve the problems of allocation or, as the case may be, reallocation. This is the area where TVA's unique directive for water management made a difference in looking at alternate policy and procedures for operation of it's reservoir system. In addition to the explicit directives for flood control, navigation, and flood control, the TVA Act also charged the agency with the implicit directive to "...provide for the general welfare of the citizens" (TVA Act). A complete river basin was used as a planning unit, overlapping the boundaries of seven states. The potentialities of the river and its tributaries could be developed under a single agency for the benefit of the entire region, not just for a single project. In addition, the first TVA Board set the precedence by attacking water management on two fronts, control of water in the streams through the construction of large dams to provide the traditional benefits and control of water on the land through encouragement of private initiatives and public institutions based on cooperative experiments, demonstrations, and studies. Engineering and scientific skills drove the first approach; administration and diplomacy the second.

The same strategic approach that TVA applied to water control on the land would later provide the framework for addressing future water management issues not specifically mentioned in the TVA Act, including recreation and water quality. The process worked well and TVA was able to make major changes in operating policy and procedures without the litigation and polarized interest that has driven decision-making in most U.S. river basins.

CONFLICT - AVOIDANCE AND RESOLUTION

Conflict over the use of water resources has usually developed as the needs and desires of society has changed, while the systems serving them were built for "survival" purposes (Ungate, 1995a). The constituencies that support these projects are enfranchised by law. Other people take the survival benefits for granted or decry their environmental impact, and increasingly value other benefits. The likelihood for this change was partially recognized by authors of the TVA Act as documented by Gilbert White. In his book. Strategies of American Water Management, he states that "TVA became the exemplar of a combination of multiple-purpose projects in an entire drainage basin with a clear intent to promote social change...and to consciously plan for shifts in income levels and modes of life". Even with this opportunity, TVA was slow to act. Even though TVA was one of the conservation movement's greatest experiments, it took about two decades for TVA river managers to recognize that the conservation movement had evolved into the environmental movement.

The traditional conflicts exist within the Tennessee Valley just as they do in all other regions. As Goranflo points out (TVA, 1989) the intensive development and use of water resources to satisfy a wide variety of beneficial purposes has created various water use conflicts. Water withdrawn for irrigation, domestic, commercial, or industrial supply can adversely affect navigation, recreation, or power production. Flood control operations often conflict with power production and recreational uses. The list goes on.

Social life styles continue to change. More and more people have both the time and money to find a refuge in the great outdoors from the stress and complexity of modern life. Wise business people rapidly capture this change and provide a myriad of recreational use opportunities, including sport fishing, boating, personal water craft, resorts, second homes, wind surfing, and whitewater sports. Social awareness of and demands for changes in environmental consideration is growing, resulting in new legislative mandates, such as the Electric Consumers Protection and the Endangered Species Acts.

These new demands have lead to new conflicts outside the boundaries traditionally addressed by us, as water managers. For example:

- Protection of the snail darter under the Endangered Species Act delayed completion of the Tellico project in the Tennessee Valley while water quality issues and endangered species led to the cancellation of the partially completed Columbia project.

- Upstream and downstream states in the Missouri Basin have sued over the impacts of flow from upstream storage projects.

- Upper Mississippi River Basin states are pondering the Galloway report recommendations on how to manage that river after the devastating 1993 flood.

- The comprehensive study of the ACT-ACF is scheduled to end this fall with no feasible alternatives identified or evaluated to date. This could pave the way for continuation of litigation between the states over allocation of water in federal projects. A proposal for an interbasin transfer from the Tennessee Valley is a distinct possibility as an alternative to meet future water supply needs of the Atlanta area.

- Perhaps the strangest, albeit most interesting, case involves the Endangered Species Act being in conflict with itself in the Columbia Basin, where alternatives that might improve habitat for the salmon threaten reservoir dependent species upstream that also are in a protected status.

The complexity of these conflicts have resulted in extended delays of workable solutions and monumental costs. Much knowledge in dealing with these issues has been gained and a few projects have successfully reached conclusion without delay and litigation, including TVA's intensive study. The Lake Improvement Plan was completed in just over 3 years and at a cost of just over $4 million. What lead to it's success? In the words of Chris Ungate, "the success ... can

be attributed to people, timing, and institution" (Ungate, 1995). I would add that, as pointed out earlier, the trap of status quo, or not setting precedence was so ingrained that the magnitude of flexibility and authority that existed had not previously been seriously examined. The right combination of inquisitors and decision-makers came together at the same time. Equally important, the TVA Board was fully empowered to initiate and fund the study, and the subsequent implementation.

FORMULATION OF THE LAKE IMPROVEMENT PLAN

Once again borrowing from Ungate (Ungate, 1992) two approaches were used to formulate the basis for decision-making by the TVA Board. The first, decision analysis, was used to identify creative approaches, gather accurate, relevant information, evaluate alternatives, and incorporate the values of all interests into the process. The second, the NEPA process, was used for public and interest group communication, assuring all issues and alternatives were identified and all points of view considered.

Decision analysis was conducted in four phases with formulation and evaluation of alternatives by all stakeholders and TVA staff. The scope was gradually narrowed in each phase to focus on key issues. A strategic decisions consultant helped guide TVA in the decision analysis approach. The NEPA process was used to hold public meetings and scope the study, to conduct the environmental evaluation, and to complete the environmental impact statement.

These processes were necessary to create a level playing field. In the Tennessee Valley environmental and recreational interest had limited standing as compared with the traditional actors of power, flood control and commercial navigation. A level playing field was necessary to provide equal consideration for all interests and to provide the decision makers with a sound basis for either changing or maintaining the status quo.

PROVISIONS OF THE LAKE IMPROVEMENT PLAN

The Lake Improvement Plan provided for increased minimum flows affecting all mainstream and tributary dams, effectively recovering more than 180 of the 210 miles of aquatic habitat affected when power was not being generated at tributary dams and thus shutting off the flow of water. The dissolved oxygen content in the river below 16 TVA dams was increased, with the objective being 5 mg/L for warm water fisheries and 6 mg/L for cold water fisheries. Summer recreation level targets were established at 10 tributary lakes, carefully chosen so they could be reached or exceeded in 90 percent of the years. Only in years of severe drought would the targets not be met.

Meeting dissolved oxygen targets required the development and installation of aeration equipment at 16 dams over a 5-year period at a cost of about $50 million. Annual operating costs are about $5 million per year. Meeting summer recreation levels cost about $2 million per year in lost hydropower value.

Congressional appropriations are used to cover the power costs because the primary recipients are recreation and economic development. Power revenues were used to pay for the minimum flows and aeration because low flows and low dissolved oxygen were the result of the design and operation of dams for hydropower purposes.

In addition, the plan made recommendations for promoting a balanced use of reservoir shorelines and improved communication with lake users. These recommendations included an accelerated development of land management plans, improved data base for reservoir lands, extension of the planning process to include marginal strip land (the final EIS has just been released for review), placing higher priority on implementing reservoir land management plans, improved communication about real-time reservoir operations (toll-free lake information line received nearly 1 million calls in 1995), efforts to increase public understanding of TVA lake and river operations and land management policies, provide opportunities for public input to river system planning and management, and work closely with other agencies in the seven Valley states responsible for water resources to address issues of mutual concern.

OUTLOOK FOR THE FUTURE

As we look toward the 21st century, the focus in the southeast will be on increased involvement in water management by the states, increased emphasis on improved quality, re-thinking the traditional methods of evaluating the 'worth' of water, reallocation of existing supplies, enhanced tools to evaluate demands, risk analysis for flood control, and re-evaluation of conventional usage of water for a hydropower peaking resource. (Brooks, 1994).

At present there is a massive effort underway by most Tennessee Valley states to increase their technical expertise in water management similar to the effort that has already taken place in the Western states. As the water supply becomes tighter, conflicts are developing between upstream and downstream states in the same watershed vying for increased benefits from the usage of a fixed resource.

Increased emphasis on water quality issues has been a central theme throughout this seminar. Certainly the outcome from all the studies and recommendations will focus on improved water quality. In addition, new organizations in each of our agencies will be formed to work with property owners, industries, and municipalities to prevent pollution from reaching the river. The protection of the water resource is primary if the rivers we have are to serve the increasing population with ever increasingly complex needs.

The traditional methods valuing the water must change if we are to accomplish the primary needs to protect it's quality and make it available for the public good. Everyone expects water to be clean and usable, to be plentiful, and to be free. When a municipality wants to increase rates to enhance treatment, public outcry is loud and clear. The public expectation of a free glass of water at a restaurant and a free fountain at every corner must be changed if past usages are to be modified to meet future need.

This seminar has looked hard at reallocation. Reallocation in the future must go well beyond current thinking if the supply is to meet the demand. In the southeast regional allocation in a watershed, or even within adjacent watersheds is a must if water is available where needed for the most public good. Ultimately, a southeastern regional management may be needed is supply is to meet the demand in the most economical way.

Enhanced analysis and decision support tools are currently under development in most agencies. A lot of these are for a reservoir by reservoir, or use by use approach. Little has been done to develop joint, large, regional models that evaluate tangible and non-tangible uses of water.

Flood control will become increasingly important as the value of riverfront development increases, increasing the value of flood storage in upstream reservoirs. In direct conflict will be the lakefront property owners and lake users who will demand moderation of the annual flood control drawdown for enhanced recreational opportunities. A possible solution would be to move away from a more arbitrary allocation toward 'equal seasonal risk' as risk analysis becomes more common place and more trained experts are available to work in this area.

The Glen Canyon decision challenged the traditional hydropower peaking paradigm. Future conflicts here will see increased flexibility demands through deregulation of the utility industry and needs for load regulation in opposition to less flexibility from recreation and environmental interests.

SUMMARY

We as resource managers must work more intensely than ever to protect the resource we value. The issues will continue to increase in complexity. At the same time, public ownership of water management systems is being challenged in Congress. Bills were introduced last year to privatize TVA, sell DOE's power marketing agencies, and look for buyers for at least a portion of the Corps projects.

As both the societal values of water and institutions responsible for its management change, new paradigms must be developed if we are to successfully meet customer demand. Allocation and conflict management are part of the tools. Stakeholders must be viewed as equal partners if future efforts are to be successful without the costly litigation that is stalling many processes today. River management institutions must be changed to include providing leaders with the responsibility and authority to make decisions, providing a broad, multipurpose authority for river basin management, and providing accountability to the customers they serve through active partnerships. Uncertainty and conflict will abound. The future is exciting. It's up to us. Thank you.

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EXPERIENCES IN WATER RESOURCES ALLOCATION AND CONFLICT RESOLUTION IN THE LOWER COLORADO RIVER BASIN, TEXAS

by

Quentin W. Martin[1]

INTRODUCTION

The Lower Colorado River Authority (LCRA) is a water conservation and reclamation district created by the State of Texas in 1934. It has a statutory service district of ten counties in Central Texas, covering approximately 10,000 mi^2 (Figure 1). LCRA operates a major reservoir system, called the Highland Lakes, on the lower Colorado River, and provides approximately 650,000 acre-feet of surface water annually for municipal, manufacturing and irrigation purposes. Approximately 70% of that supply is used for agriculture, specifically the irrigation of rice in Colorado, Wharton, and Matagorda Counties.

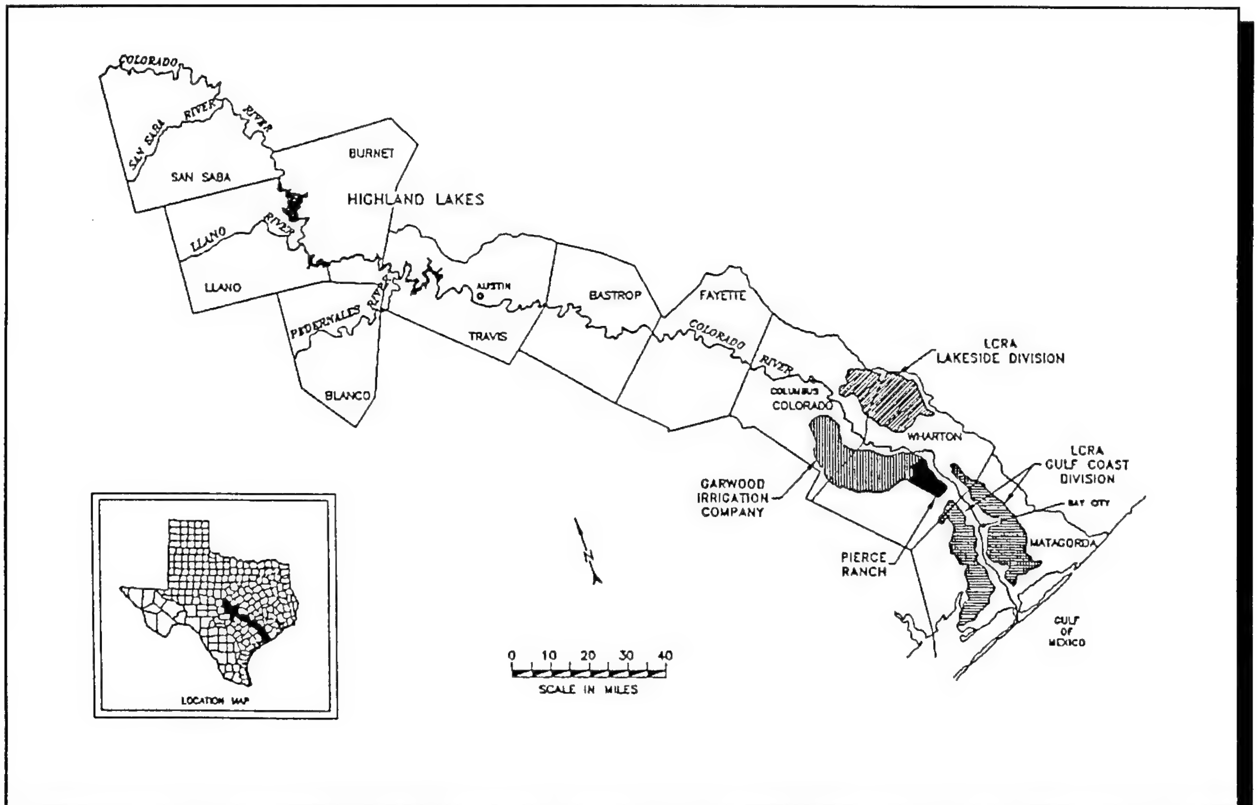

Figure 1. LCRA Statutory Water District and Major Rice Irrigation Areas

[1] Chief Water Resources Planner, Lower Colorado River Authority, Austin, Texas

After a long series of negotiations, the water rights for the Highland Lakes were adjudicated in 1988 with a settlement agreement between the LCRA, City of Austin and the Texas Water Commission (TWC). Under this settlement, the LCRA was granted the right to use 1,500,000 acre-feet annually from the Highland Lakes. As part of this settlement, the LCRA was required to complete the Water Management Plan (WMP) for the Highland Lakes and lower Colorado River which would determine the amount and allocation of the Combined Firm Yield of both Lakes Buchanan and Travis. The amount of water above this firm yield is considered interruptible water and may be sold only on a interruptible basis subject to annual availability and certain rules and conditions required by the TWC.

In 1989, the LCRA completed and the TWC approved the WMP, subject to the development of a drought management plan, and allocation of firm and interruptible water for maintaining instream flows and freshwater inflows to the Matagorda Bay estuarine system. The drought management plan was prepared by the LCRA and approved by the Texas Natural Resource Conservation Commission (TNRCC) in 1990. In 1992, the LCRA developed instream flow needs for the lower Colorado River and modified the WMP to provide water to meet those needs. TNRCC approved these changes in late 1992 pending a decision on the priority for interruptible stored water for meeting instream flow ecological needs (LCRA, 1993). Legal briefs were submitted a TNRCC hearings examiner in October, 1993 by all parties. A decision by that examiner is still pending.

KEY ELEMENTS OF THE WMP

The WMP is a comprehensive and complex (LCRA, 1993). The major elements of the WMP are discussed in the following sections.

Water Management Concepts. The Highland Lakes and the Colorado River are managed together as a single system for water supply purposes. LCRA manages the system to maximize the beneficial use of water derived from inflows below the Highland Lakes. LCRA also manages the system to conserve the waters stored in the Highland Lakes.

All demands for water from the Colorado River downstream of the Highland Lakes are to be satisfied to the extent possible by run-of-river flows of the Colorado River. Inflows are passed through the Highland Lakes to honor downstream senior water rights only when those rights cannot be satisfied by the flow in the river below the Highland Lakes.

Firm Water Supplies. The firm, uninterruptible commitments of water from Lakes Travis and Buchanan may not exceed the Combined Firm Yield or maximum dependable water supply during the critical drought of record. The Combined Firm Yield of Lakes Buchanan and Travis has been determined to be 535,812 acre-feet. To supply existing firm water demands during a repetition of the critical drought would require an average of 424,600 acre-feet per year to be released or diverted from storage in Lakes Buchanan and Travis. The present allocation of firm water supplies is given in Table 1.

Table 1 Contracts and Board Resolutions for Committing Firm Water Supply (as of December 31, 1994)	
PURPOSE	**ANNUAL COMMITMENT (Acre-Feet)**
Water Sale Contracts for Municipal, Industrial, and Irrigation (firm irrigation contracts)	84,409
Houston Lighting and Power (South Texas Project)	5,680
Colorado River Municipal Water District (O. H. Ivie Reservoir)	90,546
City of Austin	148,300
LCRA Power Plants	63,851
Future Beneficial Uses Reservation	50,000
Instream Flows, Bays and Estuaries	31,800
TOTAL	474,586
UNCOMMITTED FIRM YIELD	61,226

The current allocation includes 50,000 acre-feet of the remaining Combined Firm Yield reserved for the future needs of many areas within the LCRA 10-county district that are now using ground water supplies which are becoming depleted or are of poor water quality. This reservation will be reevaluated in 1998 based on the results from the LCRA Integrated Water Resources Plan (IWRP) for the LCRA water service area. The IWRP is presently scheduled for completion in 1997.

Interruptible Water Supplies.

1) Allocation of Interruptible Water Supplies. The water from Lakes Travis and Buchanan is available on an annual, interruptible basis as long as LCRA's ability to meet the demand for firm water is not impaired. The procedure for supplying interruptible water is described in detail in the WMP (LCRA, 1993).

   The four downstream irrigation operations (Gulf Coast, Lakeside, Garwood and Pierce Ranch) have first priority for all the interruptible stored water in the annual allocation process to the extent of their Conservation Base acreage or Priority Allocation acreage. This acreage is essentially the maximum annual usage under their existing water rights.

In recognition of the importance of recreation and tourism demands, additional sales of interruptible stored water, other than for the four irrigation operations, are limited based on the projected volume of water in Lakes Buchanan and Travis, as of January 1 of each year. No sales will occur if either lake is less that 94% of its maximum conservation capacity. If both lakes are projected to be at their maximum conservation capacity on January 1, then such interruptible water sales will be limited to a total of 80,000 acre-feet for that year. For projected lake volumes between 94% and 100% of conservation capacity, such interruptible water sales will be limited proportionately, based on the storage reservoirs with the lowest projected percentage of capacity on January 1.

2) Drought Management Plan (DMP). The DMP describes the process to be used in allocating interruptible stored water. The key elements of the DMP include the following:

   a) A 10 year time period from 1990 - 2000 is the time frame for the Plan.

   b) The DMP establishes criteria for the curtailment of stored water that is committed through contract or by LCRA Board resolution.

   c) Establishes a criteria for interruptible water supply curtailments which protects firm demands, establishes a Reserve Storage Pool, and provides for gradual curtailment in order to protect the full demand of first crop rice in all years of the critical drought. The key threshold storage levels used in the DMP are indicated in Figure 2.

   d) <u>Open Supply</u> occurs when the projected January 1 combined storage in Lakes Travis and Buchanan is greater than 1.4 million acre-feet (or about 67% of capacity).

   e) <u>Gradual Curtailment</u> occurs in stages between 1.4 million acre-feet and 325,000 acre-feet of combined storage on January 1.

   f) <u>Cutoff</u> of interruptible supply for the coming year occurs when combined storage is less than 325,000 acre-feet on January 1.

   g) <u>Review</u> and cancel the curtailment of interruptible stored water for the irrigation districts at any time during the year prior to July 31, <u>if</u> the combined storage of Lakes Buchanan and Travis is projected to be equal to or greater than 1.4 million acre-feet anytime in July.

   h) <u>Reserve Storage Pool</u> cutoff of all interruptible supplies at any time when the combined storage is less than or equal to 200,000 acre-feet.

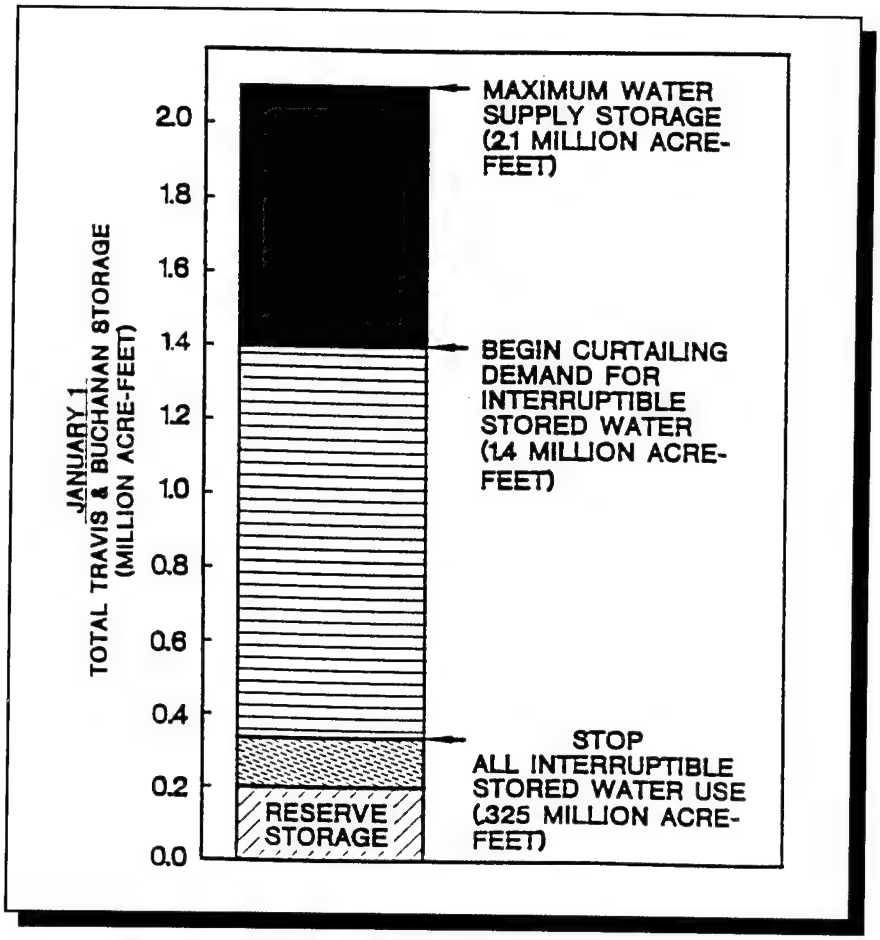

Figure 2. Conceptual Lakes Management Plan

i) Allows each irrigation operation the option, during times of stored water supply curtailment, of either: (1) a fixed maximum amount of interruptible stored water for that year, or (2) all the water necessary to cultivate a maximum acreage agreed upon by the operation and the LCRA.

j) The LCRA will request voluntary curtailment of firm water demands when there is a curtailment of interruptible water supplies and/or the total combined storage in Lakes Buchanan and Travis is less than 1.6 million acre-feet.

k) The LCRA will request that all LCRA firm water customers reduce water use by their end users when the combined storage for Lakes Travis and Buchanan is at or below 900,000 acre-feet.

l) During a drought more severe than the Drought of Record, LCRA will curtail and distribute the available supply of firm water among all of its firm water supply customers on a pro rata basis according to their demand for stored water. All uses of interruptible stored water will be totally cutoff prior to and during any mandatory curtailment of firm stored water supplies.

<u>Commitments to Instream Flow Needs</u>.

1) Instream Flow Needs. In 1992, LCRA developed two sets of instream flow needs for the freshwater ecosystems in the lower Colorado River: (1) critical flows and (2) target flows (Mosier, 1992). Each flow need is described in the following sections.

   The critical flows are considered to be the daily minimum flows needed to maintain a viable aquatic habitat for fish species. The critical flows are:

   a) Minimum daily flow at the United States Geological Survey (USGS) Bastrop streamgage of 120 cubic feet per second (cfs),

   b) Minimum daily flow at the USGS Austin streamgage of 46 cfs, and

   c) Minimum daily flow at the USGS Bastrop streamgage of 500 cfs from the period April 15 through May 31.

   The first critical flow is based on the need to provide adequate dissolved oxygen levels in the river. The minimum flow at Austin represents a flow necessary to preserve the river flow at no less than the lowest seven day average flow that would be expected once every ten years. The final flow critical flow is that needed to provide adequate spawning conditions for the Blue Sucker fish species. This species is considered an important indicator species and potentially a threatened species.

   A second set of instream flow needs (Target needs) are those which maximizes the available habitat for the fish species in the lower Colorado River. The Target instream needs are not considered as biologically critical since the native species in the river are adapted to highly variable river flow conditions. The Target instream needs are indicated in Table 2.

<u>Allocation of Water Supplies to Instream Flow Needs</u>. In the WMP, the instream flow needs are met by the release of stored water from the Highland Lakes to:

1) Maintain the daily river flows at no less than the critical instream flow needs in all years.

2) Maintain daily river flows at the target instream flow needs in those years when water supplies for the four major irrigation districts are not curtailed, to the extent of inflows each day to the Highland Lakes as measured at the upstream streamgages.

3) Maintain a mean daily flow of 100 cfs at the Austin streamgage at all times, to the extent of inflows each day to the Highland Lakes as measured at the upstream streamgages, until the combined storage of Lakes Travis and Buchanan reaches 1.4 million acre-feet. A mean daily flow of 75 cfs, to the extent inflows each day to the Highland Lakes as measured at the upstream streamgages, will be maintained until the combined storage of Lakes Travis and Buchanan reaches 1.0 million acre-feet,

then a subsistence/critical flow of 46 cfs will be maintained at all times, regardless of inflows.

Table 2 Target Instream Flow Needs for the Lower Colorado River			
Month	**Target Daily Flows (Cfs)**		
	Bastrop	**Eagle Lake (Near Columbus)**	**Egypt (Near Wharton)**
January	370	300	240
February	430	340	280
March	560	500	360
April	600	500	390
May	1030	820	670
June	830	660	540
July	370	300	240
August	240	200	160
September	400	320	260
October	470	380	310
November	370	290	240
December	340	270	220

This policy fully meets the most important instream flow needs at all times and meets the desirable (Target) flows during periods of normal or above normal streamflow conditions. The third criterion noted above was added after negotiations with the City of Austin. Austin did not believe sufficient instream flows were provided at the Austin streamgage under the Target instream needs.

To fully honor this instream flow commitment, the LCRA has allocated an average of 31,800 acre-feet per year, during any ten consecutive years, from the Combined Firm Yield of the Highland Lakes.

Allocation to Meeting Freshwater Inflows Needs of Matagorda Bay. An interim minimum freshwater inflow requirement is specified at Bay City in the WMP. This interim minimum annual inflow is 272,000 acre-feet, with a minimum mean seasonal inflow of 375 cubic feet per second (cfs) and a minimum mean monthly inflow of 200 cfs.

The LCRA is presently studying the freshwater inflow needs of Matagorda Bay.

FUTURE CHANGES TO THE PLAN

The LCRA is required by the TNRCC to revise the WMP in 1996 to take into account the freshwater inflow needs of Matagorda Bay. The appropriate volumes and timing of freshwater inflows are currently be evaluated by the LCRA in cooperation with the Texas Water Development Board, TNRCC and Texas Parks and Wildlife Department. The study is expected to be completed by February, 1996.

The WMP will be revised in 1996 to balance the water needs for all purposes including Matagorda Bay. As part of that revision these water needs will be determined for the period 1995 through 2005. The present schedule calls for the WMP revisions to be prepared and submitted to the LCRA Board of Directors for approval by June, 1996. Upon Board approval, the revised plan will be submitted to TNRCC for its approval. It is anticipate that a major contested hearing will occur that will require at least one year to complete. The primary issue will be on the priority of interruptible stored water, with the LCRA wanted to continue to give first priority to the rice irrigation districts and the Sierra Club wanted first priority to go to instream flows and estuarine freshwater inflows.

LESSONS LEARNED

What has the LCRA learned in the last eight years developing and revision the WMP? Some of the major lessons are noted below.

Priorities for Water Use Change but Change Slowly. The Highland Lakes were developed for flood control, water supply and hydropower generation. Over their fifty years of operation, a significant economic and tourism industry has developed, as have a number of residential communities drawing residents to the beautiful natural setting. In response to the concerns of the tourism industry and their political representatives, the LCRA management proposed setting the priority of water use for recreation equal to that of rice irrigation. The responses from the rice producers, their communities and political leadership were swift and severe and forced adoption in the WMP of the traditional and historical priority of rice irrigation over recreation. Recreation and tourism interests continue to strengthen and will likely make further attempts to change the historical and institutional priorities governing water use.

Involve the Public Early in the Process. It is essential to let the public and the special interest group know what you will be doing as early as possible. Providing such information before work begins helps to generate a feeling of trust.

Form an Advisory Group Composed of Representatives from the Major Interest Groups. Before any process begins, identify the major interest groups and make sure that are invited to be part of an advisory group helping the agency responsible for preparing a plan. Invite personally those key members in each group that are opinion leaders within the group.

Acknowledge and Appreciate Role of Advisory Group. Let the advisory group know what you would like them to do. Mark sure that they understand their role is to advise and not to

make decisions on what the authorized agency will do. Treat each member as a valued source of information and representative of their particular interest group.

Keep Advisory Group Informed and Solicit Input on Technical as Well as Policy Issues. Met frequently with the advisory group on major topics. Send the group briefing paper on any issues and interim reports on any technical tasks. Tell the group that you expect them to read the material sent. Perform special studies if requested by the group and give the group the results of those studies promptly. Try to take the advise the group provides and include it within your decisions.

Develop a Standard Set of Models That Represent the Technical Elements Being Evaluated. It is impossible to come to agreement on any topic if there is no standardization in determining the technical "facts". Develop a standard methodology to evaluate the impacts of alternative management policies. Document and explain, to the advisory committee and others, the workings of the methodology and share it with whomever wishes to have it.

Try to Keep the Same Membership in Future Advisory Groups. A great deal of time should be used to educate and inform the advisory group members. Don't waste it by recruiting many new members whenever you a revisiting an older policy issue. Invite former members to new advisory groups, even if those persons were somewhat troublesome in their defense of their special interest. It's the responsible agency's job to balance competing interests - not the advisory group.

TECHNOLOGY ALTERNATIVES FOR FUTURE CONFLICT RESOLUTION

We live in the information age, but the water resources profession generally tries to solve conflicts in water management as though we live in the 1950's. There is technology available that could be a tremendous aid to water managers in resolving difficult water issues. Over the last decade, the Operations Research community has developed a suite of pc-based computer programs for solving multi-attribute decision problems (Logical Decisions, 1995; Expert Choice, 1994; Applied Decision Analysis, Inc., 1994; Visual Thinking International Ltd.,1994).

The literature in water resources management has numerous papers over the past five years on potential application of such models to solve complex water management problems. Recent examples are papers by Reitsma, et. al. (1996); Stewart and Scott (1995) and Thiessen and Loucks (1992). These are generally academic demonstrations of the use of the models and not actual case studies. Although there is a significant gap between the theory and actual application of these decision support models, actual application of these techniques to complex water management problems are appearing in the literature (Walker, et. al., 1994).

With the wide availability of comprehensive yet flexible interactive computer programs, there is a great potential to improve the process for making water resource management decisions that reduce the likelihood of future conflicts between interest groups. The following section describes the use of decision analysis techniques to plan the future electric resource development program at the LCRA.

LCRA APPLICATION OF MULTI-ATTRIBUTE DECISION MODEL TO ELECTRIC RESOURCE PLANNING

The LCRA has experience in using decision support models in planning its future electric power generation. The development of the LCRA's latest Integrated Electric Resource Plan (IERP) (LCRA, 1994) used the Logical Decision computer program. The LCRA Resource Planning and Regulatory staff determined the alternatives, goals, measures and preferences needed by the model.

The process used a variety of measures to determine the impacts of a variety of alternative resource decisions. These measures are indicated in Figure 3.

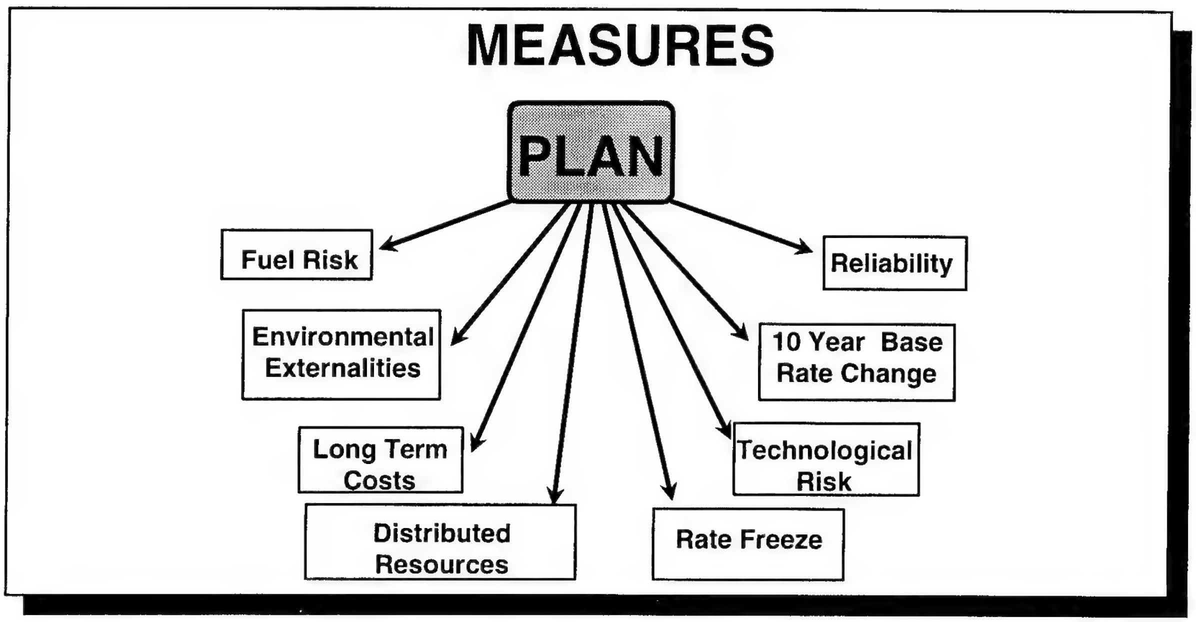

Figure 3. Impact Measures Used in LCRA IERP (Source: LCRA, 1994)

A variety of weighting factors were applied to each measure. These factors were grouped into consistent sets termed goals. Each interest group considered had its own goals or set of measure weights. An example of weights assigned to environmental advocate groups is given in Figure 4.

A number of alternative plans for meeting the power needs were developed. A final group of 15 were examined in detail and analyzed using the Logical Decision model for all interest groups and over a range of possible futures. The results of that analysis for the single future scenario equivalent to the status quo is shown in Figure 5. The total "utility" or value of each alternative is indicated over all interest groups goals. The "best" plan is one that has the largest utility ordinate where one is the maximum possible. The vertical bar for each alternative spans the highest and lowest total utility received across the four group goals used in the analysis. The line within this range represents the weighted average of the four total utilities. The graphical representation in Figure 5 provides an extremely useful format for displaying the results of the decision analysis.

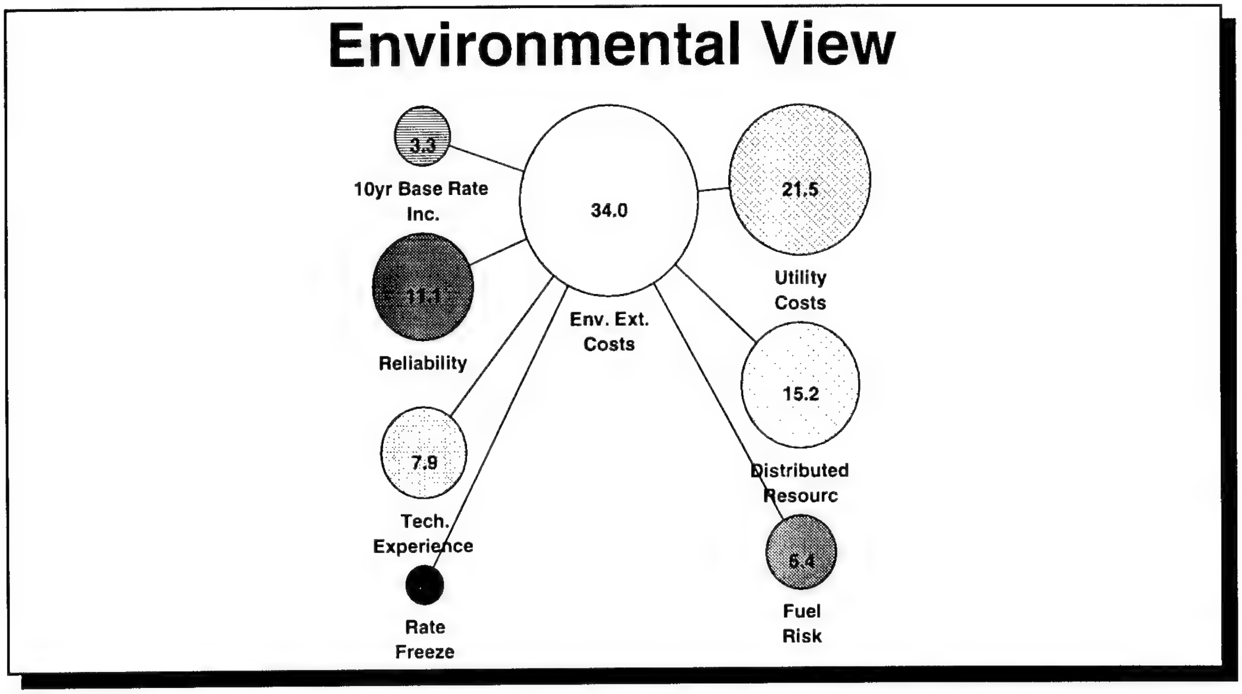

Figure 4. Preference Weights Used in LCRA IERP to Represent Environmental Advocate Organizations (Source: LCRA, 1994)

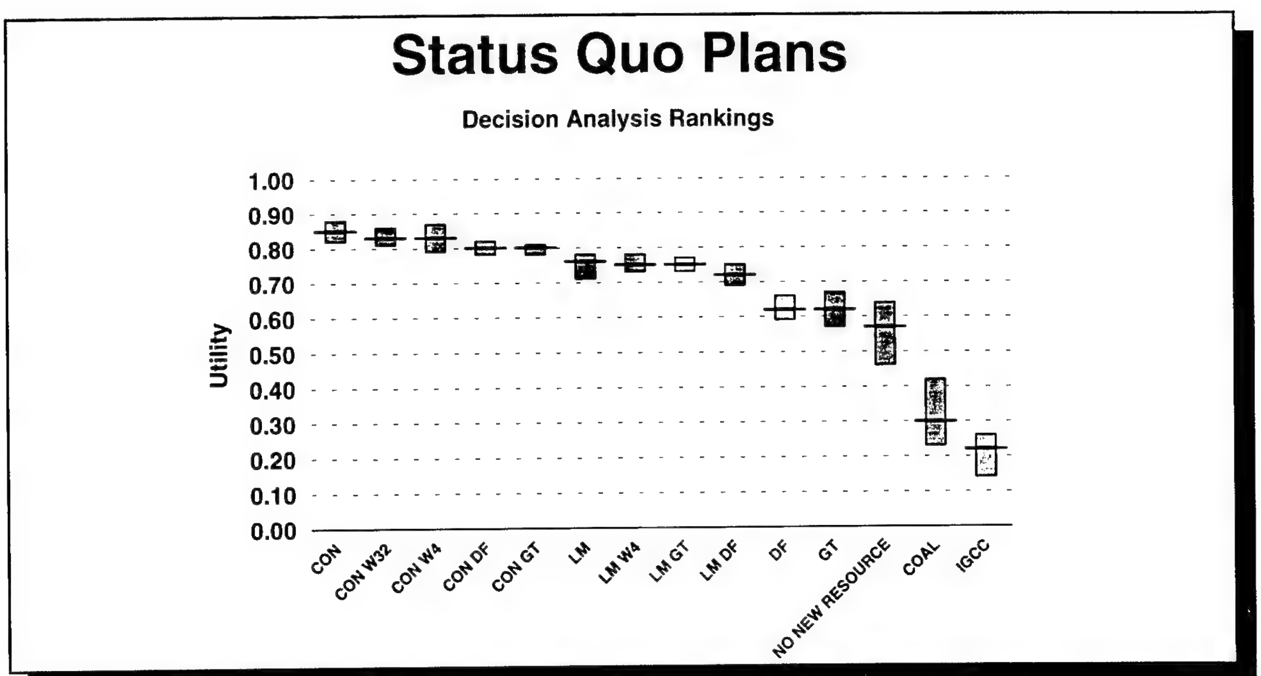

Figure 5. Results of Logical Decision Model for LCRA IERP under Status Quo Future Condition Scenario (Source: LCRA, 1994)

The LCRA found decision analysis extremely useful in organizing and evaluating the numerous alternative plans and objectives considered in the development of its IERP.

These techniques were also found useful by LCRA staff in evaluating the composite environmental impacts of potential low water dams on the lower Colorado River (Patek, et. al., 1995).

Future applications of decision analysis techniques are planned in the development of the Integrated Water Resources Plan for the LCRA water service area.

CONCLUSIONS

The Lower Colorado River Authority is charged with providing water resources for a variety of often competing purposes. The development of a comprehensive Water Management Plan for the lower Colorado River in Texas has tried to balance the allocation of surface waters from the LCRA's Highland Lakes system of reservoirs to meet these completing uses during both normal and drought periods.

The application of decision analysis techniques hold great promise as tools for reducing future water management conflicts by providing greater understanding and cooperation between the diverse water users and interest in the lower Colorado River basin.

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MANAGEMENT OF THE COLUMBIA RIVER SYSTEM

by

Nicholas A. Dodge[1]

INTRODUCTION

Management and control of the Columbia River stem from three levels; law making, policy making, and operations. Each level generally forms an umbrella for the succeeding one. The boundaries between them are somewhat murky because management authority is divided among so many different organizations, many of which spring from specific legislative acts. This makes the institutional system quite pluralistic. To appreciate the complexity of this pluralistic system, one look at legislation aimed at establishing the Federal Government's role in the relatively uncontested function of flood control reveals at least five Congressional acts which set out a major charter for the Corps of Engineers (COE). These acts recognize flood control as a national problem, the solution of which is in the interest of general welfare. They prescribe the principles of economic justification, cost sharing, recognition of interstate compacts, furnishing of lands and easements; hold the government free of damages incident to the work; define O&M criteria; and establish flood control functions for other Federal and non-Federal projects. The point here is that each water resource function has a similar but often more complex hierarchy of legislation which is routinely interpreted by several entities and it is through this interpretation that the many institutional arrangement (reflecting policy) are consummated.

When the project's commissioning date is established it is included in what is known as system operational planning, that is, rule curves and specific operating criteria are developed for both the project and the system so they can deliver the commodities that were forecasted possible in the original planning studies. In the Pacific Northwest this is done through the Pacific Northwest Coordination Agreement (PNCA) and the Columbia River Treaty, both considered to be "policy" level type documents. These documents assure a coordinated plan of system operation which defines load carrying capability of the project and system, interchange schedules between utilities, in lieu deliveries and returns, sets up storage payments for downstream beneficiaries, defines operational procedures, etc. Fundamental to the agreement is a provision which allows a priority implementation of non-power requirements. There are countless other agreements between various entities having an interest in the resources of the river which reflect each entity's role in compliance with Congressional Acts. In additions there are literally hundreds of ad-hoc agreements made monthly/weekly/daily, which bear on the day-to-day operations. In short, the way the Columbia River is managed is by negotiation and contract or agreement.

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Fortunately many functions can effectively co-exist and consequently make joint use of the water supply. For example, flood control and hydroelectric power production are generally compatible in the Columbia River Basin. In the fall and winter months the natural flows in the basin are usually at their lowest levels of the year. Water must be drafted from reservoirs to produce enough hydroelectric power to meet regional needs. This effectively provides space in the reservoirs needed to control and store the spring runoff to reduce flooding.

However, there are functions that are not compatible. Most of the functional conflicts in this region occur between fishery requirements and hydropower and between recreation, fishery, and hydropower. The fishery requirements are incompatible when they require more water to be released than is needed for firm electric loads or when they require water to be spilled past a project instead of being used to produce electricity. Recreation impacts the low-cost hydroelectric system when its limitations on summer draft reduce the amount of low-cost hydroelectric energy that is available to meet summer loads. Recreation also often requires spring refill targets that are high enough to limit winter draft for power. When a special interest group requests a different mode of operation to benefit them, often it negatively impacts another function(s).

REGIONAL POWER ACT

During the decade of the 1970's the region's utility industry was severely hindered by various environmental and consumer groups in the process of siting new thermal power plants now that nearly all hydro sites were taken or otherwise made unavailable. Therefore in 1980 Congress passed the Regional Power Act to empower the our Pacific Northwest states to make siting decisions on a regional basis. Another feature of the act was a provision to preserve anadromous fish. The Power Planning council, created by the legislation issued its first fish and wildlife program in 1982 with a major feature called a "water budget". The purpose of the water budget was to increase the regulated flows in the Columbia River for salmonids on their spring journey to the Pacific Ocean and it was to be implemented by the Corps of Engineers. The Council cannot direct the Corps of Engineers to comply with its program but in almost all cases the Corps of Engineers has voluntarily executed the program where it could do so. In the 10-year period 1982-92 the Corps continued to implement the various amended water budgets supplemented by collection/bypass systems and special fish barging.

IMPACTS OF THE WATER BUDGET

The water budget reversed the institutional role of storage, which was previously evacuated to meet winter energy loads and to provide flood control space preceding the spring freshet. This new strategy impacted the Pacific Northwest as 80% of the region's generation is produced by hydropower. The impact is a decrease of 800-1000 average megawatts.

The flood control function has escaped serious impacts so far but initiatives set out in the fish and wildlife programs and other documents have caused the Corps to defend its policy by fine-tuning the flood rule curves and studying the potential regulations that will control to higher river stages than they presently do.

In the ten-year period, 1982-92, there has not been a comeback in salmon, and the region continues an acrimonious debate which pits one opinion vs another against a paucity of hard data. Most scientist believe dams are not the sole problem for salmon. These technicians believe that the so-called "4-Hs" are the key to salmon's survival, i.e., harvest, habitat, hatcheries and hydro. However, hydro is the most visible and massive, hence it gets the most criticism. Habitat can be either in-river or the Pacific Ocean where salmon spend three of their four years reaching maturity. Yet we know very little about where the salmon goes out there, where or how it feeds and conditions necessary for its survival. It's sort of a black hole.

ENDANGERED SPECIES ACT (ESA)

In 1992 several salmon stocks were listed by the National Marine Fisheries Service (NMFS). In 1994 the Kootenai white sturgeon was listed by the U.S. Fish and Wildlife Service (USFWS). From 1992-1994 unique Biological Opinions (BO) were issued each year by the listing agencies and beginning in 1995 after several trips to court a three-year BO was published which increased by an order of magnitude the impacts to power and in addition, impacted navigators, irrigators, re-creators and communities dependent upon recreation. Harvest was severely curtailed, and those Indian Tribes covered by the 1855 Treaty were insensed. One of the ironies of these documents was that the flows called for could not physically be delivered, at some control points the probability was less than 5%. Yet they were deemed essential by the fishery community. See Figures 1&2 for past and current regulation of Dworshak and Libby projects.

The North Pacific Division staff has differed with the fishery community on numerous occasions, however, we defer the biological calls to NMFS & USFWS. The states and tribes feel left out of the decision making process and are quick to pressure NMFS & USFWS by way of media releases and trips to the courts. Since 1992 NPD has been to court about 15 times usually as a co-defendant. To prepare depositions or serve as expert witness has added a considerable burden to water management personnel already staggered by increased consultations, negotiation and coordination that has resulted from the ESA process.

In 1995 the Montana governor's office confronted NMFS on the operation of Libby Dam for salmon. Montana's claim was that operation in accordance with the BO was wrecking their resident fishery (some of these fish are proposed to be ESA listed) and destroying the local communities' cash flow from tourism. NMFS reduced the flow targets published in the BO and characterized as "absolutely essential" just a few months before. One might speculate that this unilateral decision was to decrease the threat of court action by the state but nevertheless destroyed the credibility of the BO. Canada has alleged that the U.S. Government (the U.S. Entity) has violated the Columbia River Treaty for operating Libby Dam for salmon and sturgeon and seeks mitigation for damages for loss in generation at the Lower Kootenay power plants. This matter is now pending before the State Department.

Most of the fishery community favors a heavy spill program for all projects on the lower Snake and Columbia Rivers. As the magnitude of spills increase, supersaturated nitrogen also increases causing fish in supersaturated water to be impacted by the "bends". Our policy is that we will not spill in excess of the state standards (110% supersaturation) unless the state provides

a waiver and it's the fishery community's responsibility to obtain the waiver. Montana and Idaho have been reluctant to issue waivers because they know that more water could be drafted from headwater storage. There is strong opposition to do this originating from local communities who feel their businesses are being severely impacted. The spill advocates next move was to attack the COE's total dissolved gas monitoring program which measures the supersaturation levels, hoping to discredit it. So far the COE has been able to hold the attackers at bay but there is little doubt the battle will start again in 1996.

CONCLUSION

There are many more examples of strife in operating the Columbia River system these days, and it will probably continue some years into the future. As long as someone's piece of pie is going to get smaller because of changing priorities there is going to be turmoil. Basically the system is headed for an operating mode that moves it towards the pre-dam era. It is unfortunate too that fishery decisions are based on poor data but there is also the commonly perceived notion that this is not just a question of science but one of who controls the Columbia River.

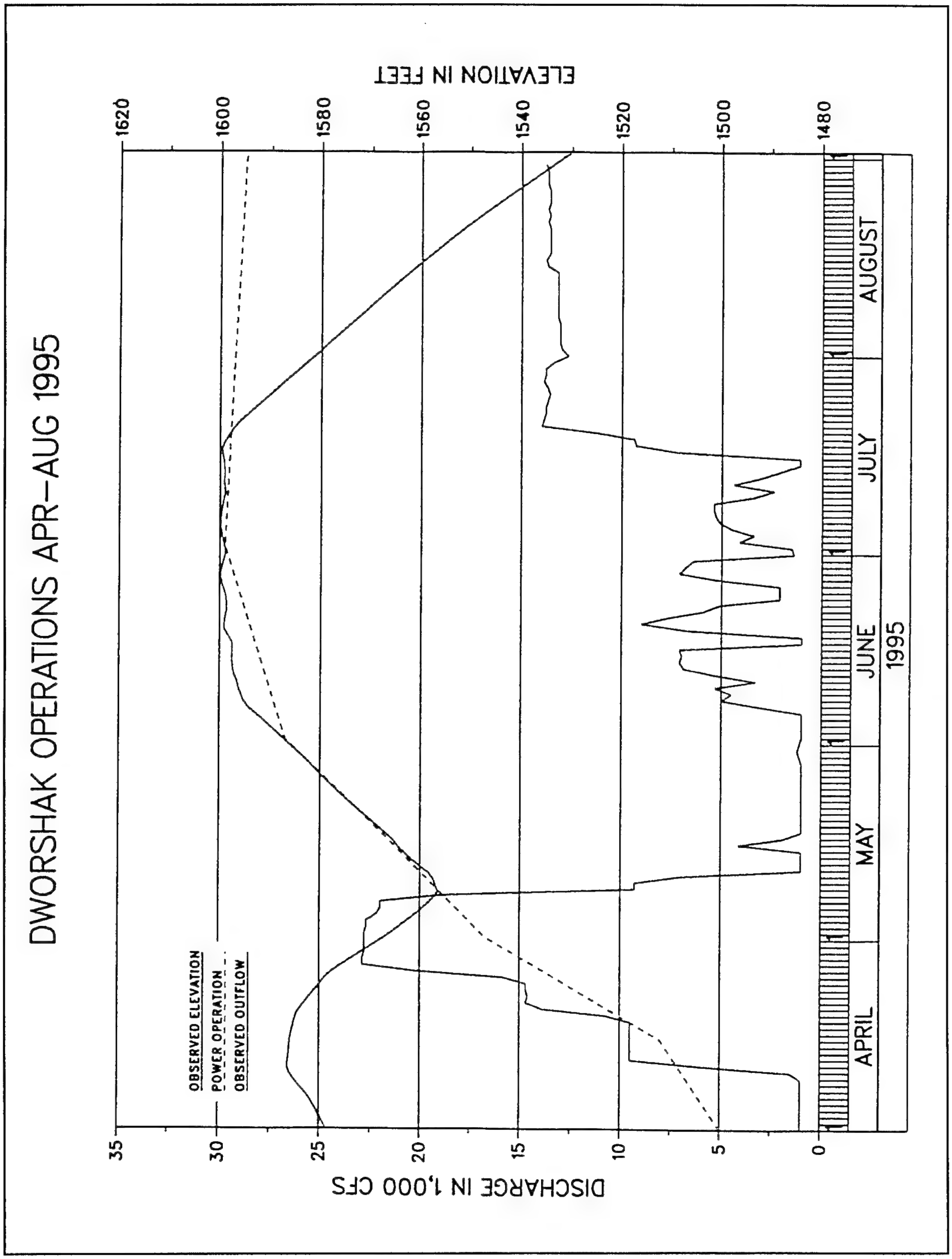
DWORSHAK OPERATIONS APR–AUG 1995
OBSERVED ELEVATION
POWER OPERATION
OBSERVED OUTFLOW
DISCHARGE IN 1,000 CFS
ELEVATION IN FEET
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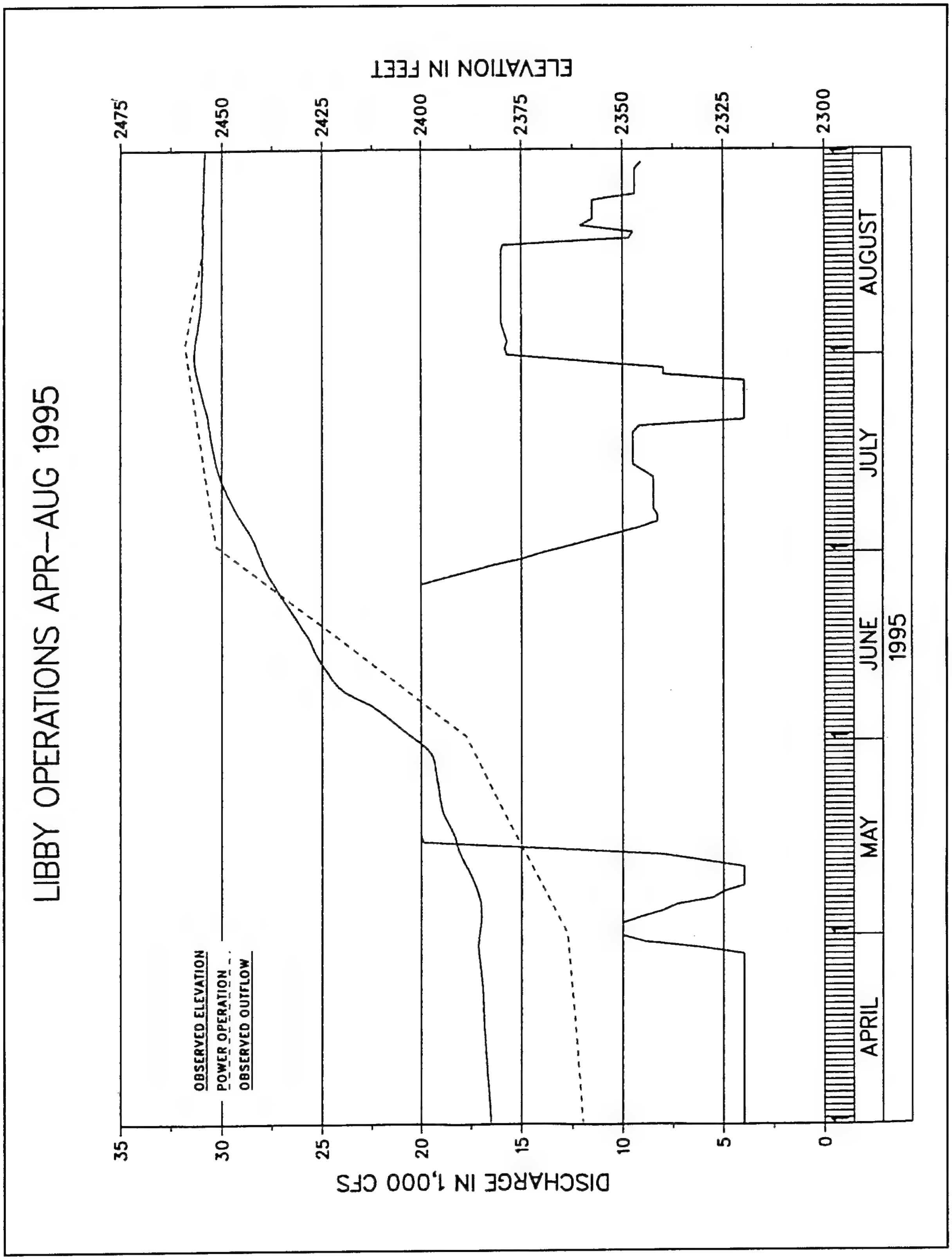
Figure 1


LIBBY OPERATIONS APR–AUG 1995
ELEVATION IN FEET
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DISCHARGE IN 1,000 CFS
35
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OBSERVED ELEVATION
POWER OPERATION
OBSERVED OUTFLOW
APRIL
MAY
JUNE
JULY
AUGUST
1995

Figure 2

CORPS WATER CONTROL REGULATIONS - RESOLVING WATER USE CONFLICTS

by

Ron Yates[1]

The *Drought of 1988* in the Ohio Basin emphasized to the public that the Ohio River Basin did not "always" have adequate water resource to meet water use demands. In fact, there are some tributary basins where water supply is over-subscribed whenever prolonged periods of below normal flows occur. Some examples are: The Monongahela, Allegheny and Beaver Basins in the Pittsburgh District; the Kanawha Basin in the Huntington District; and the upper Kentucky Basin in the Louisville District. For the purpose of this seminar I'll describe some of the actions taken in resolving the water use conflict in these basins.

MONONGAHELA BASIN - PITTSBURGH DISTRICT

The Municipal Authorities of Westmoreland Country (MAWC) and North Fayette, public water supply systems licensed by the Pennsylvania Department of Environmental Resources (PADER), obtain a large porportion of their untreated water from the Youghiogheny River. The operation of these systems is currently regulated by Water Allocation Permits issued by PADER which establish a maximum daily withdrawal based upon minimum acceptable flows which serve to ensure that water quality and low flow augmentation are not compromised. As a result of current and projected increases in potable water demand, and recent regional drought conditions, these water authorities are exceeding the permitted withdrawal amounts. In order to prevent a continuation of these violations, PADER directed these authorities to secure suitable additional storage to provide the needed supplemental releases during periods of low flow / high demand.

Since the Corps of Engineers' Youghiogheny River Lake is located upstream, the water purveyors contacted the Corps to explore the potential for reallocating storage to water supply. The opportunity for this reallocation may exist because recent improvements in water quality in the basin have resulted from the reduction in the area's heavy industry and mining. The region has lost a significant portion of its heavy industry which once dominated the employment base. This loss of heavy industry, as well as a reduction in the severity of acid mine pollution, has reduced the pollution load in the Youghiogheny River. Consequently, the original authorized storage and release schedule for Youghiogheny River Lake may be inappropriate.

Youghiogheny River Lake was authorized by the Flood Control Act approved on June 28, 1938, for the purposes of reducing flood stages and providing low-flow water quality control on the Youghiogheny, lower Monongahela, and upper Ohio Rivers. The project was placed in full operation in January 1948.

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The Water Resources Development Act of 1988 added downstream and upstream recreation as an authorized project purpose. However, the Act did not authorize the allocation of additional storage or the reallocation of existing storage for recreation. The Act states that the Lake will be "operated in such manner as will protect and enhance recreation associated with such project" and to the extent that recreation is compatible with other project purposes. It should be noted that downstream recreation, especially the whitewater rafting industry which draws about one hundred and fifty thousand visitors every year, is a competing water user with the lake recreation.

In December 1989, commercial hydropower was added to the project. The hydropower that currently is being generated, however, does not require any change in the previous operational procedures. In addition, the water quality of Youghiogheny River Lake currently supports an important two-story warm and cold water reservoir fishery, and a very popular cold water tailrace fishery.

Several meetings have been held with the water authorities, their engineering representatives, PADER officials, staff members for Congressmen Austin J. Murphy and John P. Murtha, and the Corps. During these meetings, the Corps' study protocol involving an initial assessment, followed by a reconnaissance effort (at Federal expense), and ultimately a cost-shared feasibility study was explained. All participants agreed that utilizing storage within the lake may prove to be a highly effective means of satisfying the changing low flow augmentation requirements.

In November 1993, the District initial assessment was approved. This assessment concluded that the potential to reallocate storage in Youghiogheny River Lake does exist. The district was authorized to begin the reconnaissance study when funding becomes available. The major tasks anticipated for this effort include the following item:

a. Review existing authorizations and operating rules.
b. Examine existing conditions within the watershed.
c. Review water supply issues.
d. Inventory possible alternative water sources to satisfy basin needs.
e. Analyze and quantify the important factors which define the potential of reallocation of storage.
f. Examine the impacts of any reallocation of storage.
g. Evaluate all study analyses and formulate conclusions and recommendations.
h. Estimate future study, engineering and construction costs.
i. Report preparation.
j. Publish and distribute report.

ALLEGHENY BASIN - PITTSBURGH DISTRICT

Conemaugh River Lake was authorized for the sole purpose of reducing flood stages on the Kiskiminetas, lower Allegheny, and upper Ohio Rivers and placed in full operation in December 1952. For many years Conemaugh operated for flood control only. The water quality of the lake was so grossly polluted by acid mine drainage that no fish or other aquatic organisms

could survive in the lake or downstream in the Conemaugh and Kiskiminetas Rivers. However, project conditions, regional needs and public expectations have changed and so must the project's water management criteria.

Sedimentation problems, seriously aggravated by erosion from extensive surface mining operations in its tributary drainage basin, forced the District to gradually increase the minimum pool elevation from 880 to 890 to 900. There have been several occasions, however, when high discharges at relatively low pools have been necessary. This has resulted in large volumes of the accumulated sediment near the dam breaking loose and creating downstream mud waves. The mud waves have adversely affected a downstream municipal water supply. In addition, the water quality has dramatically improved in recent years to the extent that the lake and tailwater area now support a limited fishery. Also, commercial hydropower was added to the project in March 1989.

At present, based on 1982 sedimentation survey data, the lake has a surface area of 800 acres and a capacity of 5,500 acre-feet at its new minimum pool elevation of 900 feet NGVD. However less than 5% of the total flood control capacity has been lost.

With the exception of a relatively narrow channel, virtually the entire reservoir from the dam upstream for approximately nine miles, has now shoaled to elevation 890 or higher. Sedimentation within the lake typically results in a clarified discharge and improved downstream water quality. Plans and studies are now in progress to achieve a permanent solution to these problems, which could possibly involve dredging silt from the reservoir for a distance of 500 feet upstream of the dam.

The improving water quality of Conemaugh River Lake could at some point make Allegheny River basin reservoir system operations for water quality obsolete, and perhaps free some reservoir storage now dedicated to water quality to other purposes. However, the existing system operation might still be necessary to control hardness, iron, manganese, and other parameters along the lower Allegheny and upper Ohio Rivers.

Many additional management opportunities involving only minor pool elevation manipulations are also feasible. For instance, in autumn, after a lower summer pool to allow for the growth of a crop of annual plants, the pool could be slightly raised to partially flood the crop and make it available to resident and migratory waterfowl, thereby producing a benefit to wildlife, bird watchers and hunters. Each scenario has some cost and no single plan will please all lake users. For example, during the early part of any summer season drawdown, there might be complaints about ugly mudflats. The pool management possibilities, benefits and costs, at Conemaugh River Lake will be explored with pertinent resource agencies and interest groups.

BEAVER RIVER BASIN - PITTSBURGH DISTRICT

In early 1991, the Mahoning River basin in Northeastern Ohio was recovering from an extremely wet 1990. Rainfall total in the basin during 1990 averaged about 50 inches. This total was the greatest since 1959 and averaged nearly 14 inches above normal. However, another drought began in January 1991. The basin experienced an extremely mild winter with little or no

snowfall. Even with the District's three reservoir projects, i.e. Berlin Lake, Michael J. Kirwan Dam and Reservoir, and Mosquito Creek Lake and the state-owned Lake Milton at their maximum water conservation level, there was concern in late February, of not being able to reach summer pool levels. As a result, the District implemented an approved deviation from the storage and release schedule by filling early at all four projects. The plan proved partially successful, as Kirwan, Mosquito, and Milton were able to attain their respective summer pool levels on schedule. Berlin, unfortunately fell about one foot short of its summer pool level. Beginning in May 1991 and continuing until early July 1992, the basin experienced its most extended dry spell since 1930. The basin received only about 70 percent of its normal precipitation and runoff. This resulted in the most severe drawdown the individual Corps' projects have ever experienced. Although the reservoir projects were able to meet all of their original authorized purposes, several issues with respect to water supply, water conservation, drought contingency planning, and recreation as project purposes were raised.

Berlin Lake operates in conjunction with Lake Milton, Michael J. Kirwan Dam and Reservoir and Mosquito Creek Lake to provide a minimum flow of 225 cfs (winter) to 480 cfs (summer) and a maximum regulated water temperature of 100°F at Youngstown. Since the closing of several steel mills in the Youngstown area during the 1970's, the flow schedule dominates over the temperature schedule.

In early 1992, none of the three Corps of Engineers reservoirs in the basin had recovered fully from the previous year's extended dry period. At the time, all three of these projects were well below their winter pool levels. Lake Milton, which is owned by the state of Ohio and provides some augmentation, did not reach its summer pool level. Also, within the basin is Meander Creek Lake, a water supply reservoir for the city of Youngstown and surrounding communities. Meander Creek Lake crested in the spring of 1992 at 75 percent of capacity. The water supply users were under a mandatory conservation decree since early March. The mandatory water conservation measures resulted in approximately a 10 to 15 percent reduction in water use.

We were very concerned that the extended dry period would exhaust the Corps' resources to provide for any downstream water quality flow regulation later in the year. As a result, we decided that it would be in the best interests of all concerned to conserve water by reducing downstream flow requirements to the minimum that would still maintain water quality standards. The Mahoning Valley Sanitary District (Meander Creek Lake) had requested that additional water be provided in the event of an emergency. Therefore, any conservation would assist them.

When we first discussed reducing the schedules, we requested the Ohio EPA to investigate the effect on water quality from a flow reduction. They used their existing water quality models to analyze several flow schedules at the Leavittsburg gage. Ohio EPA stated that a reduction in the flow schedule to 250 cfs would still maintain water quality standards, given a repeat of 1991 conditions. They felt that any reductions must be taken as a last resort and as part of a comprehensive program of conservation. The Ohio Department of Natural Resources, being very concerned about the drought situation, requested that the flow schedule at Leavittsburg be reduced to 250 cfs with the corresponding storage being saved in Berlin Lake.

The Corps felt that the Youngstown flow schedule should be reduced more than the 65 cfs passed on by the Leavittsburg schedule reduction. Mosquito Creek Lake was in the most severe water quantity condition. Mosquito was unable to recover to winter pool in the spring. The Pittsburgh District strongly recommended reducing the Youngstown flow schedule an additional 25 cfs and saving the storage in Mosquito. The total reduction at Youngstown (from 480 cfs to 390 cfs) would increase water management flexibility should the current conditions worsen.

The Commonwealth of Pennsylvania analyzed the effect of this 90 cfs flow reduction on the portion of the Mahoning River in Pennsylvania and on the Beaver River. The Commonwealth stated that a reduction in flow schedule as outlined is acceptable with their office given the extreme drought conditions in the basin.

The water quality of the affected streams would be monitored according to a plan developed in cooperation with Ohio EPA. Any serious deviation from water quality standards would be addressed by adjusting the schedule accordingly.

The approved plan reduced the downstream requirements for the remainder of 1992. On July 10, 1992, the plan was implemented with an approximate 25 cfs reduction in discharge from Mosquito Creek Lake and a 65 cfs reduction from Berlin Lake. No reduction in discharge was implemented at Michael J. Kirwan Reservoir or Lake Milton.

We congratulated ourselves on the thoroughness and timeliness of our actions. Three days after the schedule was implemented, Mother Nature showed who was ultimately in charge as great amounts of precipitation were reported throughout northeastern Ohio.

KANAWHA BASIN - HUNTINGTON

Early Gauley River Whitewater users were not satisfied with the amount and type of cooperation they obtained from the Corps of Engineers. They thought that more days of whitewater releases was not only possible, but that the Corps was not giving satisfactory explanations for their decisions. Lake users were also dissatisfied, but for other reasons. They wanted the lake to remain at summer pool for as long as possible. Low flow augmentation releases were detrimental to lake boating interests, and were a mixed blessing to whitewater interests. Private boaters could use low flow augmentation releases in the higher ranges. Commercial whitewater boaters could use the highest low flow augmentation releases, but only with severe restrictions as to the size of craft they could use, and with an increase in the crew to passenger ratio. The State of West Virginia backed the development of whitewater because it would increase tourism.

At about the same time, or possibly earlier, citizens began to petition Congress to add whitewater recreation as a project purpose at Summersville Lake. The Whitewater Advisory Panel became a forum for the interested parties to state their needs, and to work out conflicts in a way that was mutually acceptable to most parties. The Water Resources Development Act of 1986 added whitewater recreation as a project purpose at Summersville Lake. When whitewater

become an official project purpose at Summersville Lake, the Whitewater Advisory Panel became an important part of the decision process in implementing the new project purpose.

The drought of 1988 brought about a change in the basic way the interest groups thought of themselves and each other. Every group was hurt by the drought. It became attractive to the interests to look for ways to cooperate, even if cooperation broke old traditions and behavior patterns.

Augmentation from Summersville and Sutton Reservoirs for the Charleston water quality objective began in mid-June 1988. Augmentation releases were reduced on August 12 to the absolute minimum limiting value as defined by previous water quality studies. Summersville Lake was at the lowest elevation ever experienced for that time of the year. The Corps increased water quality data gathering efforts and learned to continuously sample on the run, traversing the Winfield pool daily with instrumentation. In early September significant controversy developed with the whitewater outfitters who wanted "normal" releases for the "best" whitewater experiences. However, when releases were less than optimum for the whitewater experience, the outfitters adapted and brought in smaller rafts.

On 18 September 1988, a meeting was held between representatives of the West Virginia Department of Natural Resources, Corps of Engineers, USEPA, and chemical industry to discuss extremely low flows in the Kanawha Basin, water quality concerns, and whitewater recreational issues. The participants agreed generally that the augmentation flow target for Charleston should be reduced to 2500 from the normal 3000+ cfs range, and that pulsing flows from Summersville Lake should be abated while Charleston flows are below the normal augmentation flow target. The target reduction would help ensure that flow rates below the critical minimum value (1960 cfs) would not occur.

On September 20, 1988, we met with representatives of the USEPA, Region III. The same topics were discussed. It was agreed generally to reduce argumentation flow target to 2500 cfs and that pulsing be limited to weekends and at a maximum peak of 1500 cfs as long as current conditions persist.

The State DNR considered these issues and officially supported our position on the 2500 cfs flow target and supported our position not to peak for whitewater recreation when flow fluctuations are below the augmentation targets of 3000 cfs. However, the whitewater interests continued their political campaign through the West Virginia Congressional delegation as the Corps daily answered letters in response to the situation.

At a December 1988 Whitewater Advisory Board meeting the parties came to agree in principle on how to schedule appropriate dates for both fishing and whitewater releases. The Chief of Engineering Division, encouraged this when he reminded participants that the Corps' interests were flood control and water quality, and that the Corps would operate, as much as possible, in accordance with any understandings reached between the DNR and outfitters.

The information exchange function of the Board gave the various interest the opportunity to see issues from the viewpoints of opposing interest. Incorrect assumptions were not able to withstand direct examination and discussion of issues by the assembled group. The adversarial atmosphere of the early 1980's was replaced by an attitude of cooperation by the end of the 1980's.

Recent proposals to modify summer outflows at Summersville Lake are examined by a special meeting of the board with only the most directly affected interests present. The results are discussed later in the year at the annual meeting of the full board.

The composition of the Board has remained approximately the same through the years. The dramatic increase in numbers of private boaters using the Gauley during drawdown provided the reason to add a representative of the kayaking community to the panel. Requests for special operations to support filming activities related to whitewater have become common. Although not a specific member, the Director of the West Virginia Film Office has been interested in the activities of the Board, and has become active in the work of the Board.

America Outdoors, a national organization of outdoor outfitters, presented their Agency Partnership Award to the Huntington District at their annual convention in December, 1995. To a large extent, the Corps' willingness to incorporate the feedback of the whitewater advisory panel into the operational decisionmaking process was responsible for the enhancement and conservation of outdoor recreational experiences that generated the award. Outfitters consider the Gauley River to be a model of recreational management, and it is gaining a national reputation.

UPPER KENTUCKY BASIN - LOUISVILLE DISTRICT

The Upper Kentucky Basin includes two projects - Carr Fork Lake, completed in 1976 and Buckhorn Lake completed in 1961 that provide flood protection, water quality and recreation, to communities along the Kentucky and Ohio Rivers. In the Kentucky basin is Lexington, KY, one of the faster growing areas in the Ohio Basin. Water supply for Lexington, KY comes from the Kentucky River. The hydrological situation developed in late July-early August 1988 where the Lexington, KY municipal-water company was withdrawing most of the water from the middle portion of the Kentucky River. Fortunately, ORD made the decision in February 1988 to fill the reservoir system (Normal filling would not begin until early-mid April, after the late winter - early spring rains.) Buckhorn was filled in late April, and analysis indicated surplus water was available. The drought exasperated water quality conditions in the Kentucky river below values used to develop the augmentation schedule at Buckhorn reservoir. River flows during the drought were running 10% of normal. After considerable discussion with the state of Kentucky, Lexington Water Authority, and recreational interests, we made the decision to increase releases from Buckhorn Lake to insure the maintenance of water quality standards downstream of the dam. We increased the outflow as indicated in the water control plan by 5 cfs per day for four days to achieve a total outflow of approximately 60 cfs. The increased outflow would support the water supply needs of the Lexington community during the extended period of drought. The release advanced the rate of depletion from the reservoir by less than 0.1 ft/day.

In the aftermath of the drought (seven years later), the state and the water supply company have still not solved the water supply problem. The Corps is assisting in studying the problem.

FUTURE DIRECTION

The Ohio Basin Reservoir System operational objectives need to be re-evaluated in view of changing water-use requirements. The water management plan for the Ohio Basin was formulated in the 1950's.

Reservoir construction by decade is shown in the table below:

Decade	Reservoir Construction Completed
1930	15
1940	11
1950	7
1960	23
1970	17
1980	4
1990	1
TOTAL	78

ORD has a mature reservoir system. Currently there are zero reservoirs in either the advanced planning, the design or construction phase. Our challenge is to better manage the available water resource. To do this we need to restudy Ohio basin objectives. We cannot continue to patch single reservoir or tributary system changes without looking at the system effects.

HOW WE CONTRIBUTE TO CONFLICT - MY OPINIONS

by

Bob Watson[1]

BACKGROUND

I. South Atlantic Division

The South Atlantic Division(SAD) is a regional headquarters for the Southeastern portion of the United States for Corps of Engineers activities. Within SAD are five districts, four of which have a water management mission. These four are Wilmington, Savannah, Jacksonville and Mobile. The Charleston District does not have a traditional water management mission.

II. Within the Mobile and Savannah Districts are several multi-purpose reservoirs with purposes to include fish and wildlife, flood control, hydropower, navigation, recreation and water supply. The majority of the large storage projects in SAD were constructed and put into operation in the 1950's. From the mid-50's until the early 1980's, the hydrologic conditions in the Southeast were generally above average from a volume standpoint. This long period of time with above average hydrologic conditions defined expectations on the part of the public as well as government agencies.

III. In 1981, a severe one-year drought occurred in the Southeast. A 12 month period in which flows were the lowest of record for any recorded 12 month period for many stations. The hydrologic conditions recovered in the intervening winter of 1982. Typically, winter is the wet period in the Southeast (excluding South Florida), with the months of January - April being critical to refill of the projects.

IV. In the period 1985-1989 a very severe, extended drought struck the Southeast. This drought, using prime flow as a measurement, was about 20 percent worse than the previous drought of record.

V. At the start of the 1985-89 drought, our drought management plans and water control plans were essentially non-existent. Consequently, whenever cutbacks were made in releases, they were done through "negotiation" and with great conflict; not by using an existing water control plan, which is a statement of the management strategy of operating the reservoirs.

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VI. The conflict that occurred was basically and upstream/downstream conflict. The navigation interest desired dependable navigation in the lower river; the hydropower interest desired that their "contract" amounts be met. By contrast, the recreation interest desired a full(or near full) pool and water supply desired dependable water supply.

VII. In addition to the conflict associated with this drought, I have been involved in and aware of the conflicts associated with the operation of the Central and Southern Florida Project(C&SF). The C&SF projects consists of Lake Okeechobee and several huge water conservation areas that provide water supply to the east coast of Florida (say south of Miami to north of WPB); and water supply for the Everglades National Park. Additionally, the C&SF provides flood control for the municipal areas along the east coast.

VIII. The everglades were historically much larger than it is today. In fact, the everglades, at one time, stretched from the southern portion of Lake Okeechobee to the southern tip of Florida. A portion of this area was drained by various agricultural and drainage districts and large agricultural areas were developed in this fertile area.

IX. The present day situation is that the Everglades National Park is a "next door neighbor" with agricultural areas owned by groups with great political influence. This juxtaposition and dynamics has led to conflict.

DISCUSSION

Mr. McClure and Mr. Vearil have discussed the ACF-ACT and the C&SF in detail at this meeting. I will attempt to relay some generated observations I have made relative to conflict.

X. Clear communication is essential in "conflict situations" to minimize the conflict. This sounds like a simple task but it clearly is not. The "factual information" surrounding a water resources matter is held by a number of different groups in the same agency, to include those familiar with recreation, hydropower, navigation, etc. These different interest interpret these facts differently, even though they work for the same agency, and without close coordination, their everyday communication of these facts will contribute to conflict.

XI. Interagency disagreements and "mis-speak", whenever they get outside the agency contributes to conflict. For every policy issue that potentially can lead to conflict, the agency needs a clearly defined and communicated position. Furthermore, any "internal dissidents" must be reminded continuously of the official agency position.

XII. An official agency position relative to the operation strategy of a water resource is essential in controlling and managing issues and resulting conflict. In the Corps, we refer to this strategy as a water control plan. The water control plan is a statement of our strategy of operating the projects during normal hydrologic events, and extremes such as droughts and floods.

XIII Internally, it is important to come to an agreement relative to the authority of the agency to operate the project in differing manners. Generally, the Corps has been given great discretionary authority in operating our projects. In communicating our position, it is confusing and "conflict laden" to blame a decision on "authority", when, in fact, the authority rest with the agency and the decision was really the agency's view of what was in the best overall interest, given its authority. Also, keep in mind that "authority" is clearly a legal matter, not a technical one; confusing this can lead one to make "authority" calls without being "founded on the facts".

XIV. Conflict in water resource related matters is not a short-lived event. It is not akin to a family squabble which will end as suddenly as it began, but rather water resource conflicts will last months and more likely years. Consequently, the rhetoric can become more and more conflict laden, until the purpose of much of the communication of the two groups will be "strategic" rather than related to facts and issues. Whenever the communication between groups becomes more a matter of "winning" than "solving problems", it has, in my opinion, reached this strategic level. A game of "point/counterpoint" only elevates tensions and conflicts and solves nothing; but we have a tendency to move to this mode after a prolonged debate of the issues.

XV. Technical matters can only be understood and appreciated by engineers, or at least that what some of us think. This position leads to conflict. We must strive to communicate our positions and findings in non-technical ways.

XVI. Not understanding our roles within the organization is a "conflict enhancer." The Districts are design/technical experts, the division the regional interface and quality assurance group, and the HQs is the "policy maker". For any of these groups to get out of their "role" in talking with the interested public causes conflict in that it will certainly lead to an agency speaking with "more than one voice" and will give an opportunity to "divide and conquer" when viewed from outside the agency.

CLOSING

The above are some of my experiences related to conflict and water resource projects and I will be happy to answer questions as part of the panel discussion.

WATER QUALITY AND ECONOMIC FACTORS IN WATER MANAGEMENT

by

Jerome B. Gilbert[1]

INTRODUCTION

As the 20th Century draws to a close, it is interesting to reflect on the evolution of water management. The focused development and harnessing of water resources to achieve two principle objectives, water supply and flood control, supported our economic growth and population expansion in an extraordinarily successful way. By mid-century, however, elected officials and planners recognized the need for broader objectives and the evaluation of projects based on objective criteria. As competition for public investment grew more intense and the largely justified faith in the ultimate future need for large projects was questioned. Existing projects, although justified when interest rates and construction costs were low, are also called into question. Looking back on the mid-century, it is now clear that capital investment in infrastructure related to water became so large, that it began to compete with the increases in transportation, and to some extent social spending of the 60s. As we approach the end of the century, water management takes on a very different, less coherent and to some extent, chaotic aspect.

The old drive for order and logic in the form of multi-purpose basin plans that incorporate all considerations, seems to have given way to processes that evolve in each area, depending on the politics, organization, needs, and competing interests. It is very clear that the hierarchical era of a fundamentally responsible agency, and perhaps individuals incorporating all project information and balancing in one organized continuum, did not exist, and, at least for the foreseeable future, will not exist, however theoretically desirable it may be.

This paper will explore some of the factors that affect water management, create conflicts, and determine allocation. Allocation is an interesting concept because it implies an accounting type of approach distributing the water (and the costs) in proportion to pre-determined public policy priorities. In fact, the distribution is more likely to be based on the currently strongest advocacy positions and a consensus program resulting therefrom. Thus, consensus water management involves skills, not usually available in the water community; and the compromises that are necessary to make a project politically acceptable may not be optimal of resource management.

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WATER QUALITY

Balancing. When the California legislature adopted the Porter-Cologne Act of 1969, it intended to start the integration of water quality and water quantity considerations. The sections creating basin plans for the State of California, while not incorporated into water resources planning, which under law was the province of the Department of Water Resources, nevertheless included water quantity considerations. These were to be controlled by the water rights decisions of the State Water Resources Control Board. Although it controls all uses permitted since 1914, and it directly enforces reasonable use under the Constitutional provisions, the Board does not do so in the context of a quality/quantity plan.

While California has made much progress in deciding both on waste discharge and water rights giving consideration to the respective quality and quantity objectives, the management and control systems are separate to this day. In an effort to extend this broader concept on a nationwide basis, the Congress adopted Public Law 92-500, the Clean Water Act, in 1972, which incorporated a series of planning sections, beginning with section 208. Again the objective was to create coherent comprehensive plans to manage water quality. A great deal of money was spent on plans which included the first efforts at water conservation and control of non-point source pollutants. However, these plans were developed largely by regional governments, which, in recent years, has become less politically acceptable and hence lack implementation authority.

The balancing of competing quantity and quality interests has also been an unintended result of the state and federal environmental reporting laws. Notwithstanding their increasingly complex criteria and litigatory character, they serve the unintended value of requiring comprehensive view of individual projects that are proposed either to improve water quality or to alter or improve water quantity management. In many instances, the environmental processes have been the vehicle to prevent actions so that rather than resolving conflicts, the conflict prevents the realization of the public benefit that could flow from, for instance, a storage reservoir to mitigate drought, a new waste water reclamation plant to reduce the demand on traditional resources, or solid waste disposal facilities that would eliminate the current impacts resulting from existing facilities.

Surface Waters. The quality of surface water is an increasing factor in water management throughout the country. In California, the major historic quality issue has been salinity intrusion in the Sacramento/San Joaquin Delta. This is directly related to outflow which, while originally natural, has been significantly altered by the construction and operation of large storage reservoirs. Ideally, the water quality factors that effect surface waters in the Sacramento/San Joaquin drainage basin, would be managed in a holistic way so as to minimize investment while improving water quality.

In practice, each water quality factor is independently evaluated and increasingly regulated to achieve a water quality that would exist in a state of nature. As a result, these standards or objectives can rarely be achieved and the benefits and costs of investments are not balanced. Some of the specific activities that effect quality include:

1) Stream alteration and mining. 19th and early 20th Century mining has created major changes in water quality and stream configuration in California. Remedial action, although recognized as necessary several decades ago, is gradually being constructed. Litigation continues over issues relating to the responsibility for meeting extraordinary high standards for heavy metals in the drainage water, even during times of high run-off where dilutions are large. The control of abandoned mine drainage can be accomplished through storage, and if storage is exceeded during rainy periods, the concentrations of discharge would be so low as to be insignificant.

2) Irrigation drainage. In the great Central Valley of California, the millions of irrigated acreage produce significant quantities of drainage water that comprise a large portion of run-off, particularly during the late Summer and Fall periods. Initial basin studies of pollutants in this drainage basin and recent watershed sanitary surveys, have indicated little evidence of pesticides, herbicides or other industrial pollutants in Delta waters. Nevertheless, the use of very large quantities of chemicals has been of latent concern. It has been commonly believed, particularly by the environmental community, as well as the public, at least in Northern California, that there is a direct relationship between the recent decline of fish populations and the quantity of water exported to Central and Southern California by the state and federal projects. Although professionals have had some skepticism of this conclusion, no hard data exists to contradict it. An interesting recent theory shows not a correlation between striped bass mortality and exports, but a correlation between that mortality and a reduction of phytoplankton in the tributary waters to the Delta. This reduction is probably due to herbicides used in the rice farms of the Sacramento Valley. If this is true, a different control strategy will be needed, perhaps including on-farm controls, alternate chemicals, etc., and the constraints on the water pumping to the South from the Delta can be changed.

3) Organic Materials. The Delta area is subject to significant loadings of organic materials due to upstream drainage and drainage discharge from the Delta islands. In addition, the influx of nutrients and temperature conditions produce a good environment for aquatic growth. Unfortunately, these conditions form the precursors of regulated chemicals that are produced in the drinking water process. Although treatment processes are being improved to minimize these compounds and related taste and odors, controlling them at the source would be preferable. One control is to divert water used for consumption around the Delta area, but this creates problems as identified elsewhere in this paper.

Groundwaters. Groundwater provides the water supply for a large part of the nation and generally does not figure directly in water management schemes. However, to a limited extent in the San Francisco Bay Area and to a major extent in Southern and Central California, groundwater basins offer an opportunity to store water in conjunctive use programs to provide for groundwater use during the years of drought.

The Metropolitan Water District of Southern California has recognized this potential in its recently adopted Integrated Resources Plan by providing subsidy programs for three types of groundwater usage: a recovery program to assist in the treatment of contaminated groundwaters, a cyclical storage program that allows the storage of water during the wet years for recovery in dry years, and a seasonal storage program that allows storage in the winter for peak use in the

summer. These subsidy programs are designed to minimize drought conditions, such as those that occurred in 1991. In that year the State the purchased water from agricultural users and delivered it through the State Water Project to Southern California. The future need for this water can be reduced if stored groundwater is available.

The first major GRP project is currently underway in the San Gabriel basin east of Los Angeles. This basin, which has a storage capacity of about 10 million acre feet, has an average annual use of about 250,000 acre feet. The vast majority of this is recharged naturally. It is eligible for Metropolitan Water District subsidies, but the use of the groundwater is increasingly restricted by the movement of a contamination plume, generated by past industrial activities. Under CERCLA requirements of EPA, an industry committee has been formed to implement a remediation project. If the water is made usable, it can be delivered to local purveyors of drinking water supplies either to off-set the present need for imported water from the State Water Project, or to double groundwater pumping capacity so that the groundwater could be used to a greater extent in dry years.

Thus, a potential quality improvement, drought protection and perhaps ultimately, cost reduction program, might be advantageous to all concerned. A project has been proposed that involves about 30,000 acre feet of water that would be treated to standards acceptable to the Metropolitan Water District, delivered to its system in lieu of deliveries it makes to other customers nearby. The current problem is that, while the project makes economic and environmental sense, the industries involved are required to make an upfront payment for their share of the project which will be operated over a 25 year period. Thus, it is necessary to come to agreement on cost sharing principles today for costs that will not be incurred for many years in the future. In addition, there is the local watermaster that controls the recharge and extraction of water from the groundwater basin under a court jurisdiction.

The conflict resolution in this case is an evolving consensus approach to a plan that can be financed, accepted, and operated to the satisfaction of all interested or concerned parties in a way that will minimize future risks and costs.

Safe Drinking Water. The Safe Drinking Water Act of 1974 did not initially have a significant impact in water management. Treatment improvements were achieved by projects to meet maximum contaminant levels (MCLs). Occasionally compliance required selection of a new source rather than high levels of treatment; but this was more the exception than the rule. Utilities proceeded to generally improve treatment of surface waters without extraordinary increases in cost. However, with the 1986 amendments to the Safe Drinking Water Act required that all service waters be filtered. An exception was allowed if it could demonstrated that watersheds would meet eleven criteria for the protection of public health. While only a few cities using surface waters do not use filters, they are major ones, including New York, San Francisco, Seattle, and Portland.

1) The New York City is supplied with water from a historic set of public works projects. Two 14 foot deep rock aqueducts deliver water from large storage reservoirs located in the Catskill, Delaware, Croton watersheds to provide nearly three billion gallons a day to the New York region. The 2,000 square miles of watershed in Catskill and Delaware are occupied by

30,000 head of cattle; 50,000 septic tanks; several dozen small communities, not to mention resorts and assorted industries. In an effort to comply with the exception rules of EPA, the City of New York has proposed comprehensive watershed management programs including land use controls, the construction of waste treatment facilities, and land acquisition to minimize the risk of pathogens entering the New York City system.

To achieve this objective, the City initially proposed to spend about $300 million (now a billion dollars), and EPA has granted their request. This is based on a belief that the treatment facilities would cost $8 billion, but when an independent EPA panel reviewed the matter it estimated the cost of a plant at perhaps, 20% of this amount. In this conflict situation, the politics of New York's cost aversion and environmental advocacy are sufficiently powerful to off-set the development of cost-effective approach including treatment. Environmentalists see restrictions on use of the watershed as a way to control growth and preserve the watershed, both of which are necessary and desirable, but not an alternative to providing appropriate levels of public health protection through modern, efficient treatment.

2) The Seattle the situation is different. Its two sources are largely municipally owned watersheds. Nevertheless, the animals and vegetation in these waters result in contamination from natural causes that cannot be effectively controlled, even though humans are excluded from the watersheds. Thus, Seattle must find some improvement in treatment technology and has, in fact, agreed to filter and/or to provide equivalent treatment. However, Seattle is short of water and must either obtain additional supplies in conjunction with Tacoma to the south, or firm up its present sources. Seattle has demonstrated, in developing these approaches to treatment, a level of community involvement and consensus building that can serve as a model to other areas. Groups concerned with public health, economics, the various state, federal, and local agencies, has been successful so far in developing consensus positions.

WATER QUANTITY

In California and the southwest , water quantity conflicts can be simplified into a relationship between the continued storage and diversion of water for off-stream consumptive use and those flows that are allowed to remain for in-stream beneficial uses, principally fish. The combination of the issues described under quality and these in-stream uses will effect the cost and desirability of all future water projects. Determining water project yield in the face of wide-ranging rainfall amounts has become easy compared to determining what in-stream flows will achieve fish benefits.

The Sacramento/San Joaquin Delta is a case-in-point. The recently hailed December 15th Agreement and the Central Valley Improvement Act (CVPIA, 1992) have resulted in the lowering of the intensity of the dispute between competing interests in California.

There now is a five year planning program called the Cal/Fed Planning Process. All involved are hopeful that the process will create enough information so that consensus can be extended and the dispute over outflow, Delta water quality pumping for export, and Delta and San Francisco Bay environmental conditions can be resolved. However, initial indications do not lead to optimism on this score. California seems to have institutionalized the conflict. Although

the data clearly shows that fish would benefit by the construction of a isolated channel to better manage flows and improve water quality, the opponents of such a project and their children and grandchildren will remain opposed. Environmental groups need to rely upon fear as a good fund raiser and would lose a principal "call to action". There are more rational and informed participants in the various competing factions; but those factions, to a significant extent, depend upon the conflict for their political credibility and, in some cases, livelihood. Recent data that shows biological factors resulting from agricultural land use activities may be the principle cause of adverse effects to the fishery is not likely to be easily accepted. Proposals to invest substantial sums in improving Delta habitats, protecting levees, etc., may not, in the end, be sufficient to result in a water management scheme that it will contribute to meeting of California's future water needs. This is a pessimistic note regarding the potential for an agreement on standards and facilities to achieve conflict resolution. However, water transfers offer cause for hope.

WATER TRANSFERS

Reallocation. The historic method of water allocation has been through regulations or water rights, agreements, contracts for service by water development agencies or water suppliers. In the West, the doctrine of "first come, first served" has prevailed, although now mitigated by the general requirements for reasonable and efficient use. This successful approach has been based on the willingness to spend money on water storage, diversion and delivery facilities. However, in the 90s, the ability to develop water is limited by availability, costs, and most importantly, environmental competition to protect public trust uses. This competition is based on legal and practical considerations. Given the fishery and water quality constraints, some of which are identified above, there would appear to be only one avenue to optimize future water use. The possibility of optimization through regulations is constrained by: regulatory efforts have difficulty considering macro or micro economics, the lack of integrated authority, and the difficulty of balancing the objective and subjective criteria. Perhaps in our evolving democratic society, more of a free market approach is the answer.

Background. Historically there have been sales, transfers and exchanges of water rights in the west. Individual districts, property owners, and agencies have sold or acquired water rights, modified existing rights, on a long-term and short-term basis. However, these exchanges, which should move water from less valuable uses to more valuable uses, have been sporadic, generally involve small quantities of water, and were not undertaken in response to formal or informal public policy. This has changed. In the CVPIA, and in recent California legislation, water transfers are specifically recognized and encouraged. This new policy, has received support when the more traditional ways of increasing the yield or firming up existing supplies cannot be achieved through construction of storage facilities or diversions. Unfortunately, past water practices frequently stand in the way of change. They include: the body of legislation prescribing water rights, authorizations of water projects, water decisions and priorities, regulations resulting from legislation, and finally, the huge body of case-law that supports the current practice.

Short-Term Transfers. Competition for limited water resources was no more clearly evidenced than in the 1991 drought in California, which fell in the middle of the five-year drought cycle beginning in 1987. The State of California recognized the severity of the drought

and its impact when the users of water from the State Water Project urged the state to purchase water from farms. The State purchased some 700,000 acre feet at $125/acre foot on a one-time basis. It turned out that only 400,000 acre feet of this water was actually used in 1991, and 300,000 was carried over for delivery in 1992. In fact the Drought Water Bank, as it was called, continued in existence in 1992, purchasing an additional quantity of several hundred thousand acre feet at a much reduced price of $50-60 per acre foot.

There were objections to transfers under this program. Local counties complained that in some cases additional Groundwater was being pumped to off-set water being transferred; others complained that the water being transferred was not water resulting from the fallowing of land but rather water that had a so-called "paper right," and still others complained about the adverse economic impacts associated with reduced farming in the areas where water was obtained. Nevertheless, this sets a precedent which is likely to be repeated in future droughts, providing local agencies have reduced water demand as much as possible through conservation measures. If that is the case, a good argument could be made for a law requiring a drought transfer program to be implemented under certain hydrologic conditions. A proactive state water program would include advanced preparations for this activity plus a database upon which it can be based.

Long-Term Transfers. California state law provides for both short and long term transfers. Short-term transfers are easier since they do not require formal water rights hearings, and do not require a full environmental impact assessment. Long-term impacts require full water rights review, environmental impact analysis and more importantly, the agreement of agencies operating the aqueduct facilities to accommodate the movement of water from the source to the area of use. In practice, this agreement has been difficult to obtain even in short-term transfers, since both the Department of Water Resources and the Bureau of Reclamation give priority to existing customers, and use their own rules to determine whether the water being transferred is legitimately transferable. Nevertheless, private citizens and public agencies are today actively seeking to enter into long-term contracts to transfer water. Although no such contracts have been perfected, some memoranda of understanding have been concluded.

It is interesting to note the range of prices associated with long-term transfers. Some entrepreneurs, anxious to obtain maximum return, have suggested that perhaps a comparable value to unit cost of developing new storage might be used, i.e.: $300-400 per acre foot at current prices. Others have suggested that if in a drought, water can be purchased for $125/acre foot, a number in that range capitalized, say between $1,000-$1,500 an acre foot on a one-time purchase, would be a reasonable price. To say the least, the market is uncertain and chaotic. In certain Northern California cities, developers have been told to secure their own water supply, i.e.: by transfer, in order to obtain building permits. In other areas water agencies have assumed responsibility. The San Diego Water Authority is negotiating with the Imperial Irrigation District (or property owners therein), to purchase a water supply on a long-term basis that would be wheeled through the pipelines of the Metropolitan Water District that has historically been the San Diego area's water provider. The real issue in long-term transfers is the security gained by a long-term contract and the efforts needed to perfect the contract worth the value? If traditional water reliability factors are applied to the current scene, the answer is "yes." But, if a sufficient effort was made to develop a short-term drought related transfer program that was statewide,

perhaps the need for long-term transfers could be reduced. The issue is the balance between proactive securing of water supply, and trust or confidence in regional or state agencies.

A number of individual agencies, land owners, and consultants are currently engaged in work on water transfers. Water transfers inherently result in the reduction of water conflicts, and they should benefit both parties to the transfer. Nevertheless, there could be third-party effects as discussed above, and these effects will result in controversy during the planning and implementation of a transfer until transfers are commonplace and procedures are accepted.

Future Role of Government. Whether viewed on a regional or statewide basis, it would seem that there is a significant role that government could play facilitate the reallocation of the water supply. A number of individual negotiations are currently underway on the Colorado Water Basin involving the Las Vegas Valley Water District, entities in Arizona, the Metropolitan Water District, and others. The availability of supply from the Colorado for use in California directly affects California's internal water transfer situation. On a more general basis, it would be helpful to develop information bases, both within California and the southwest, on the availability of water to transfer, the potential areas where water could be transferred to, and, various transfer conveyance mechanisms that might be available. This type of a clearing house or database is currently being investigated by various parties in California.

SUMMARY

This paper has attempted to review a number of factors that effect the resolution of conflicts and priorities in water management, particularly in the southwest and in California. It is clear that comprehensive planning strategies that were envisioned as resolving these competing needs are not now as effective as individual agency actions. Nevertheless, these actions should take place in some kind of an organized context to assure that they can take place and to assure that the impacts of each one, i.e.: water transfers, are properly assessed. There is a role for regional and state agencies to play in facilitating conflict resolution through water transfers; what that role will be remains to be seen.

FUTURE ISSUES ASSOCIATED WITH WATER USE CONFLICTS INTO THE TWENTY-FIRST CENTURY

by

Dennis B. Underwood[1]

ABSTRACT ***(No paper submitted)***

If history is correct, the twenty-first century will inherit many, if not all, of the water issues we are struggling with today an yesterday. And, as in the past, they will become more complex and difficult to resolve with time. The American spirit will foster the necessary technical solutions but, left unchecked, cost, financial responsibility, conflict and controversy will continue to be the enemies of progress and issue resolution.

Today's words, such as "re-inventing, re-engineering, re-structuring", and the principles of total quality management need to be carried into the twenty-first century with a focus on lengthy, and too often closed-loop, water resource decision-making processes that cost a lot but accomplish little, and institutional layering and implementation which are also costly and inefficient. Our open decision-making process mistakenly provides excessive opportunities to avoid accountability and defer decisions, and for special interests to drive or control the process.

We are fast becoming a culture driven, if not consumed, by process as opposed to a result-oriented society. Water resource decision-making processes for the past 30 years have accommodated change (i.e. water quality laws; environmental documentation and compliance; public participation; and endangered species protection, management, and recovery) in the same fashion as the automobile industry attempted to retrofit engines to meet air quality and fuel efficiency standards. Major retrofitting doesn't work and generally only invites intervention and further standards. Major retrofitting doesn't work and generally only invites intervention and further retrofitting by the courts and legislative bodies. There comes a time when you need to re-engineer the framework.

Fundamental to any framework, re-engineering effort is the reaffirmation or establishment of basic premises. We need to always be mindful that the purpose of public infrastructure is to serve the achievement of socio-economic and environmental quality of life goals and it is not an item within itself. Water infrastructure needs to be complementary. Water supply, flood control, water treatment and disposal goals and plans need to be consistent with each other and have a demonstrated composite cost-effectiveness. Decisions and evaluations should have a taxpayer or customer, not organizational, orientation.

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Besides the decision-making framework, issues which will transcend into the twenty-first century with added dimensions and complexities will be those dealing with water supply reliability, water quality, interstate water supply and river operations, federal and nonfederal financing of capital and operational improvements, greater use of existing facilities, project operations, control and ownership transfers of public facilities, assignment of costs, replacement of aging infrastructure, drought management, water rate and revenue structures, funding of general public purposes such as flood control, recreation, and fish and wildlife, and rural water supply systems.

ROLE OF THE CORPS IN WATER MANAGEMENT INTO THE TWENTY-FIRST CENTURY

by

Earl E. Eiker[1]

INTRODUCTION

Trying to envision what the Corps' role in water management will be in the twenty-first century is a difficult assignment at best. These are unsettled times within the Federal government, and with downsizing and reduced budgets our ability to continue as a viable agency will be severely tested. If we are to control our own destiny we must establish our future direction based on a principle of action rather than reaction.

In order to set our direction, we first must reflect on where we have been and where we are at this point in time. Only when we understand this history, will we be able to set our objectives and identify what we need to meet them. We must establish our future direction, or, rest assured, someone else will do it for us, and that is not in the best interest of the Corps or the nation.

EVOLUTION OF CORPS' WATER CONTROL MANAGEMENT

There is no doubt in anyone's mind that over the past decade we have moved farther and farther away from our traditional design/construct mission to a mission focused on operation and maintenance. Today we have only two dams under construction and two more in design. This is a far cry from the 1950's, 1960's and 1970's, a period sometimes referred to in the United States as the "golden age of dam construction". Almost as if by accident we have made the transition from dam builder to dam manager.

Corps water resources development programs initially focused on dam construction for purposes of navigation. These projects were low head structures which typically offered little opportunity for regulation. In the early twentieth century several dams were constructed that also included hydropower as a project purpose. Following the disastrous flooding in the Mississippi River Basin in 1927, the Corps, at the direction of Congress (Flood Control Act of 1928), began a program to provide flood control along the lower Mississippi River and Tributaries. Flood Control was made a nationwide Federal responsibility by the passage of the Flood Control Act of 1936. Section 7 of the 1944 Flood Control Act assigned responsibility to the Secretary of War (Secretary of the Army), acting through the Chief of Engineers, to prescribe operating rules for all storage projects built for the purposes of flood control and/or navigation that were fully or partially funded by the Federal government.

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General legislation was passed during the 1940's, 50's, 60's, and 70's that authorized inclusion of water supply, storage for water quality control, fish and wildlife and recreation in Corps projects. This general legislation greatly expanded the range of project purposes that could be included in Corps reservoir projects, resulting in the construction of many multi-purpose projects. Since the Corps retained responsibility for operation of these projects, water control management evolved as an important aspect of our water resources development program.

Over the past twenty years, exposure to numerous hydrologic extremes, has resulted in much attention being paid to our water management activities. For example, the combination of drought in the late 1980's and floods in the early 1990's in the Missouri River Basin has resulted in the first comprehensive restudy of the regulation of the mainstem Missouri River dams in over thirty years. At the same time, but for other reasons, comprehensive reregulation studies were also initiated in the Columbia River Basin (endangered species) and the Appalachicola/Chattahoochee/Flint Basin (water supply and hydropower). Water control management had finally come of age within the Corps.

CHANGING PUBLIC EXPECTATIONS

While this natural evolution in our water control management activities was occurring, there was also a noticeable change in public expectations taking place. The public as a whole wanted to have more involvement in determining how Corps projects would be operated on a day to day basis. This attitude was also reflected in the Congress with the passage of legislation (WRDA '90) that required the development and modification of water control plans to be undertaken with full public involvement. There was a perception on the part of the general public and the Congress, that through more intensive management of individual projects and reservoir systems, a significant increase in benefits could be realized. While many of these positions were parochial in nature, put forth by local landowners, power cooperatives or recreation interests for example, many were also a reflection of changing national priorities such as increased environmental awareness and a desire to approach water management in a more holistic manner. The ongoing reregulation studies cited above, to a large extent, reflect an attempt to address these attitudes.

MOVING FORWARD

With all the above as background, how do we now put together a water control management program that will enhance our ability to meet our responsibilities into the twenty-first century? Above all, we must recognize and communicate to the public and Congress that our projects cannot accomplish all things for all people. We must therefore be able to prioritize our reservoir operation within Congressional authorization constraints, understand and articulate the impacts of modifying current reservoir operations and more effectively communicate the logic of why we do the things we do. This must be effected in a way that allows us to still maintain flexibility to address emergency situations and to accommodate future changes in public priorities. As Vice President Dan Quayle once said, "If we do not succeed, we run the risk of failure!" The Corps and the nation cannot afford to fail in this effort.

Our program must be structured recognizing four fundamental principles. We must have the Congressional authority to develop it. We must have the internal policies established to provide consistency and make it work. We must have the technology available to form the basis for decision making. Finally, in this period of Federal government downsizing, we must have the resources, in terms of both funding and technical capability to effectively carry it out.

AUTHORITIES

Over the years Congress has delegated significant authority for water control management to the Chief of Engineers. This has enabled the Corps to regulate it's projects, particularly during emergencies, in a highly effective manner. River basin and specific project authorizations have delineated broad operating goals and objectives thus allowing flexibility in meeting these goals and objectives. General legislation, such as Section 216 of the Flood Control Act of 1970, has made it possible for the Corps to undertake studies to determine whether or not modifications to project regulation were appropriate to address new or changed priorities. With these delegations in place it is safe to say that we have the authority we need to accomplish our mission.

POLICIES

Internal Corps policies related to water control management have consistently reflected national priorities and have provided the flexibility to meet changing demands. Engineer Regulation 1110-2-240, establishes requirements for continual review and updating of water control plans, holding public meetings when plans will change, and coordination with all affected parties both inside and outside the Corps when developing new plans. It also requires that all applicable general legislation, such as NEPA, be considered when preparing Water Control Plans. Engineer Regulation 1110-2-1400, assigns oversight and coordination responsibilities to each MSC, delineates reporting requirements and sets forth the roles of the districts, MSC and HQUSACE in the conduct of water control management activities in the Corps. Clearly, the necessary policies have been promulgated.

TECHNOLOGY

The technology needed for decision support of our water control management activities can be roughly grouped into three categories; data management, runoff forecasting and reservoir modeling. These elements when taken as a whole comprise the Corps Water Control Data System (WCDS). The WCDS is made up of both hardware and software components, integrated into a single system. Within the Corps we have made considerable strides to date in developing the WCDS, but the system that is in place falls short of what we will need to meet the challenges of the next century.

We can look back with pride on our accomplishments in developing the original WCDS. During the 1980's we were able to acquire the hardware that was needed to greatly improve our ability to collect and manage large amounts of project related water data. This acquisition, along with improved software, greatly enhanced our ability to regulate our reservoir projects. Other benefits that resulted from the standardization of hardware and software within the WCDS,

include a greatly improved ability to communicate among Corps offices and non-Corps agencies and significantly reduced system development costs.

Since development of the present WCDS however, many advances have been made in hardware and software that need to be incorporated into an updated system. In addition to conversion of existing software, a major work item to improve our data management capability must be the creation of a new corporate data base using Oracle software so that it is fully compatible with other Corps sponsored data bases.

In the area of flood forecasting there is also much to be accomplished. We need to continue our efforts to incorporate weather radar information into our forecast models. We also must continue to develop our ability to use GIS information in model applications.

Over the past twenty years we have greatly enhanced our capability to apply deterministic reservoir system simulation models as a decision support tool for project regulation. However, we have not made similar progress with the development of models that will allow us to optimize system operation. We have taken the first step with the Prescriptive Reservoir Model (PRM), but we need to continue this effort. It is critical to our ability to meet future objectives that we have the capability to identify optimal operating plans, based on hydrologic, economic and other criteria, quickly and efficiently.

Recognizing the need to upgrade our currant WCDS, we have initiated an effort to modernize the WCDS over the next five years. New hardware has been acquired but there is still a considerable amount of work to do in developing the new data base and other software.

RESOURCES

Recent events have made it problematic as to how rapidly we can continue to make progress. With the elimination of the Real Time Water Control R&D Program in the FY 96 Corps Authorization Bill, funding for future development must be obtained from other sources.

Even more critical to the future of water control management in the Corps is the downsizing that is now taking place within the Federal government. As we proceed with district and MSC restructuring, it is essential that we retain the technical personnel required to assure that we can continue to meet our responsibilities. Experienced and dedicated people make the program work; without them it cannot work! We must therefore assure that institutional knowledge is protected and that our younger personnel are mentored by experienced professionals and are fully trained to get the job done.

A BLUEPRINT FOR SUCCESS

Obviously, there are a significant number of challenges facing us as we move toward the twenty-first century. Our water control management activities will expand; the public demands this and deserves nothing less. At the same time, as with all Federal agencies, we will be asked to do more, with reduced funding and personnel resources. If we are to meet the challenges ahead, we must set our direction based on the following seven elements.

1. We must seek out opportunities to stress the importance of water control management to the continued viability of the Corps as an agency and to provide to the nation the project benefits authorized by Congress.

2. We must strive to retain the delegations of authority that Congress has given us.

3. We must maintain our internal policies as a reflection of national priorities and desires.

4. We must maintain our impartiality in the face of intrusion into our day to day decisions so that we may continue to protect the Federal investment.

5. We must expand our coordination, cooperation and communication, both internally and externally, to avoid duplication of effort, expand our return on investment and keep all interested parties apprised of our activities.

6. We must identify new sources of funding such as the Plant Replacement and Improvement Program (PRIP) and partnering, as we have done in other programs, in order to continue modernization of the software portions of the WCDS.

7. We must retain our expertise and mentor our new employees to assure that the people required to make the program work have the knowledge to make it work.

SUMMARY AND CONCLUSIONS

The picture is not as bad as it may first appear. In the past we have overcome a great many obstacles. Our track record is good and I firmly believe it will continue in the future. No one group can do it alone however; not HQUSACE, not the MSC and not the districts. If we are to be successful we must all pull together. We have the authorities and policies that we need. We have a modernization plan for the WCDS that will give us the technology that is required. We have identified new and innovative financing arrangements. We have identified district, MSC and HQUSACE personnel requirements. The plans are in place. It's time to get on with the job before us!

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WORKSHOP
ON
POLICY AND PROCEDURES FOR WATER MANAGEMENT, ALLOCATION, AND CONFLICTING USE RESOLUTION

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30 January - 1 February 1996

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WORKSHOP
ON
POLICY AND PROCEDURES FOR WATER MANAGEMENT, ALLOCATION, AND CONFLICTING USE RESOLUTION

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30 January - 1 February 1996

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AGENDA

WORKSHOP
ON
POLICY AND PROCEDURES FOR WATER MANAGEMENT, ALLOCATION, AND CONFLICTING USE RESOLUTION

Agenda
30 January - 1 February 1996

Day 1 Time	Description
8:30 - 8:45 a.m.	**WELCOME AND INTRODUCTIONS** (Earl E. Eiker, HQUSACE and Darryl W. Davis, Hydrologic Engineering Center)
8:45 - 9:45 a.m.	**Paper 1: A POLITICAL AND ECONOMIC PERSPECTIVE ON WATER USE CONFLICT RESOLUTION** (Harry E. Kitch, HQUSACE)
9:45 - 10:00 a.m.	**BREAK**
10:00 - 10:45 a.m.	**Paper 2: A BUREAU OF RECLAMATION PERSPECTIVE ON WATER USE CONFLICT** (Lewis Moore, Bureau of Reclamation, HQ)
10:45 - 11:30 a.m.	**Paper 3: PRESENT WATER CONTROL MANAGEMENT POLICIES FOR CORPS OF ENGINEERS RESERVOIRS** (Earl E. Eiker, HQUSACE)
11:30 - 12:15 p.m.	**Paper 4: MISSOURI RIVER MASTER WATER CONTROL MANUAL UPDATE STUDY** (Duane J. Sveum, Missouri River Division)
12:15 - 1:15 p.m.	**LUNCH**
1:15 - 2:35 p.m.	**Paper 5: COLUMBIA RIVER SYSTEM OPERATION REVIEW** (Ray E. Jaren, North Pacific Division)
2:40 - 3:35 p.m.	**Paper 6: APPLICATION OF A PRESCRIPTIVE RESERVOIR MODEL (HEC-PRM) TO THE COLUMBIA RIVER SYSTEM** (Michael W. Burnham, Hydrologic Engineering Center)
3:35 - 3:55 p.m.	**BREAK**
3:55 - 4:30 p.m.	**Paper 7: BILL WILLIAMS RIVER WATER MANAGEMENT CONFLICT RESOLUTION STRATEGY** (Joseph B. Evelyn, Los Angeles District)
4:30 - 5:50 p.m.	**Paper 8: PRESCRIPTIVE RESERVOIR MODEL APPLICATIONS FOR BILL WILLIAMS RIVER** (Kenneth W. Kirby, Hydrologic Engineering Center)

WORKSHOP
ON
POLICY AND PROCEDURES FOR WATER MANAGEMENT, ALLOCATION, AND CONFLICTING USE RESOLUTION

Agenda (continued)
30 January - 1 February 1996

Day 2 Time	Description
8:00 - 8:50 a.m.	**Paper 9: THE ACT/ACF COMPREHENSIVE STUDY: A CONSENSUS APPROACH TO WATER RESOURCES PLANNING** (Skeeter McClure, Mobile District)
8:50 - 9:45 a.m.	**Paper 10: USING SHARED VISION MODELS IN THE ACT/ACF STUDY** (William J. Werick, Institute for Water Resources)
9:45 - 10:00 a.m.	**BREAK**
10:00 - 10:45 a.m.	**Paper 11: WATER BALANCE STUDY USING THE WEAP PROGRAM** (William K. Johnson, Hydrologic Engineering Center)
10:45 - 11:35 a.m.	**Paper 12: WATER MANAGEMENT AND THE CENTRAL AND SOUTHERN FLORIDA PROJECT** (James W. Vearil, Jacksonville District)
11:40 - 12:25 p.m.	**Paper 13: WATER MANAGEMENT, ALLOCATION, AND CONFLICTING USE RESOLUTION - THE TVA EXPERIENCE** (Arland W. Whitlock, Tennessee Valley Authority)
12:30 - 1:30 p.m.	**LUNCH**
1:45 - 2:45 p.m.	**Paper 14: EXPERIENCES IN WATER RESOURCES ALLOCATION AND CONFLICT RESOLUTION IN THE LOWER COLORADO RIVER BASIN, TEXAS** (Quentin W. Martin, Lower Colorado River Authority)
2:50 - 4:20 p.m.	**Panel Discussion:** **1: MANAGEMENT OF THE COLUMBIA RIVER SYSTEM** (Nicholas A. Dodge, North Pacific Division); **2: CORPS WATER CONTROL REGULATIONS - RESOLVING WATER USE CONFLICTS** (Ronald A. Yates, Ohio River Division); **3: HOW WE CONTRIBUTE TO CONFLICT - MY OPINIONS** (Robert M. Watson, South Atlantic Division)

WORKSHOP
ON
POLICY AND PROCEDURES FOR WATER MANAGEMENT, ALLOCATION, AND CONFLICTING USE RESOLUTION

Agenda (continued)
30 January - 1 February 1996

Day 3 Time	Description
8:00 - 8:45 a.m.	**Paper 15: WATER QUALITY AND ECONOMIC FACTORS IN WATER MANAGEMENT** (Jerome B. Gilbert, Private Consultant)
8:45 - 9:30 a.m.	**Paper 16: FUTURE ISSUES ASSOCIATED WITH WATER USE CONFLICTS INTO THE TWENTY-FIRST CENTURY** (Dennis B. Underwood, Private Consultant)
9:30 - 10:00 a.m.	**BREAK**
10:00 - 10:45 a.m.	**Paper 17: ROLE OF THE CORPS IN WATER MANAGEMENT INTO THE TWENTY-FIRST CENTURY** (Earl E. Eiker, HQUSACE)
10:45 - 11:15 a.m.	**OPEN DISCUSSION PERIOD** (Earl E. Eiker, HQUSACE)
11:15 - 11:30 a.m.	**SUMMARY AND CLOSING** (Darryl W. Davis, Hydrologic Engineering Center)

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